

**USING SPATIAL INFORMATION TO SUPPORT DECISIONS ON
SAFEGUARDS AND MULTIPLE BENEFITS FOR REDD+**



**STEP-BY-STEP TUTORIAL VERSION 1.2:
BUILDING SPATIAL WORKFLOWS TO HELP IDENTIFY
POTENTIAL AREAS FOR UNDERTAKING A REDD+
INTERVENTION USING THE GRAPHICAL MODELER
IN QGIS 2.18**

**PLUS ADDITIONAL ANNEX CONTAINING GUIDANCE NOTES ON GEOPROCESSING TOOLS AND TECHNIQUES
WITHIN QGIS, COMPARING RASTER AND VECTOR DATA ANALYSIS**

**UN-REDD
PROGRAMME**



Food and Agriculture
Organization of the
United Nations



**UN
environment**

Empowering lives.
Sustaining nature.

The UN-REDD Programme is the United Nations Collaborative initiative on Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries. The Programme was launched in September 2008 to assist developing countries prepare and implement national REDD+ strategies, and builds on the convening power and expertise of the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and UN Environment.

The UN Environment World Conservation Monitoring Centre (UNEP-WCMC) is the specialist biodiversity assessment centre of UN Environment, the world's foremost intergovernmental environmental organisation. The Centre has been in operation for over 35 years, combining scientific research with practical policy advice.

Prepared by Corinna Ravilious, Charlotte Hicks and Simon Blyth

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1. Introduction

REDD+ is a voluntary climate change mitigation approach that has been developed by Parties to the UNFCCC. It aims to incentivize developing countries to reduce emissions from deforestation and forest degradation, conserve forest carbon stocks, sustainably manage forests and enhance forest carbon stocks. This will involve changing the ways in which forests are used and managed, and may require many different actions, such as protecting forests from fire or illegal logging, or rehabilitating degraded forest areas.

REDD+ has the potential to deliver multiple benefits beyond carbon. For example, it can promote biodiversity conservation and secure ecosystem services from forests, such as water regulation, erosion control and non-timber forest products (NTFPs). Some of the potential benefits from REDD+, such as biodiversity conservation, can be enhanced through identifying areas where REDD+ actions might have the greatest impact using spatial analysis and other approaches.

The purpose of this tutorial series is to help participants in technical working sessions, who are already skilled in GIS, to undertake analyses that are relevant to REDD+. The tutorials have been used to build capacity in a number of countries to produce datasets and maps relevant to their spatial planning for REDD+, and to develop such map products. Maps developed using these approaches appear in a number of publications whose aim is to support planning of strategy options that enhance biodiversity and ecosystem services as well as delivering climate change mitigation (see <http://bit.ly/mbs-redd> for country materials). There is of course no requirement for countries to use the approaches described in these tutorials.

Spatial analysis can be used to support decision-making in order to identify potential areas for appropriate REDD+ interventions (REDD+ actions), but maps alone are not sufficient for making decisions. This does not mean that all potential interventions can be usefully mapped, but map analysis can be useful alongside methods such as stakeholder consultation and participatory mapping approaches in selecting what REDD+ approaches to apply, and where.

This tutorial focuses on how to use spatial analysis workflows to help identify potential areas where a REDD+ intervention (also known as REDD+ action, or REDD+ measure) could be undertaken to address a specific driver or barrier. Specific interventions will be suitable for addressing specific drivers or sets of drivers.

This tutorial uses an imaginary land area to demonstrate how to create and run an analysis using workflows in QGIS Graphical Modeller. It covers: mapping the drivers of deforestation and forest degradation, and barriers to the '+' activities; mapping REDD+ interventions; defining spatial logic and creating workflows; sharing the resulting model; and fixing a broken model. The annexes provide more background information on raster data formats and processing for those who are more familiar with vector GIS data, and will guide users in exploring the various raster analysis tools and methods that are available within the QGIS Geoprocessing Toolbox.

Annex 1 provides a brief summary of the differences between vector and raster data and an introduction to getting started with raster data analysis. Raster analysis provides users with access to a large number of tools and functions that are not available for vector analysis. Many of these tools are particularly suited to multi-criteria analysis. Raster functions can also be used to generate new data (e.g. hydrology and slope data from digital elevation models). It also includes a comparison table to show equivalent ArcGIS tools.

Annex 2 provides links to additional resources and guidance related to QGIS Graphical Modeler.

A similar tutorial that uses ArcGIS as an alternative platform is available from <http://bit.ly/GIStools-redd>:

Ravilious, C., Hicks, C. and Blyth, S. (2016) Using spatial information to support decisions on safeguards and multiple benefits for REDD+. Step by Step Tutorial Version 1.0: Building spatial workflows to help identify potential areas for undertaking a REDD+ intervention using model builder in ArcGIS 10.x. Prepared on behalf of the UN-REDD Programme. UNEP World Conservation Monitoring Centre, Cambridge, UK.

2. Mapping drivers of deforestation, forest degradation and barriers

When thinking about drivers of deforestation and forest degradation, and barriers to the ‘plus’ activities (conservation, enhancement, sustainable management), we often refer to the current situation (e.g. what are the drivers now and where forest cover change has already happened). But it is also important to consider future pressures and threats on forests, and how they may lead to deforestation or forest degradation, as well as future barriers.

To identify locations for REDD+ interventions, consideration must be given to both location of current drivers and barriers, and the pressures and threats on forests, to help identify where drivers or barriers may be found in the future.

Drivers and barriers may be direct or indirect. Examples of **direct drivers** include expansion of infrastructure, agricultural expansion, fire, mining activities and expansion of plantations (e.g. rubber, oil palm). A direct barrier could be physical features (steep slopes, rocky terrain, distance from roads) that prevent access for reforestation. Examples of **indirect drivers and barriers** include changes in population size and density (perhaps indicating growing demand for land and natural resources), poverty levels (perhaps indicating direct dependence on natural resources), financial incentives (e.g. commodity prices and subsidies that may make certain land-uses more desirable), cultural preferences (perhaps defining how natural resources are used) and political decisions (determining how landuses are distributed and controlled).

Drivers of change in forest cover/quality may lead to changes in forest functions, levels of biodiversity, provision of ecosystem services and support for forest-based livelihoods.

To identify and map areas affected by or at risk of drivers and barriers we can:

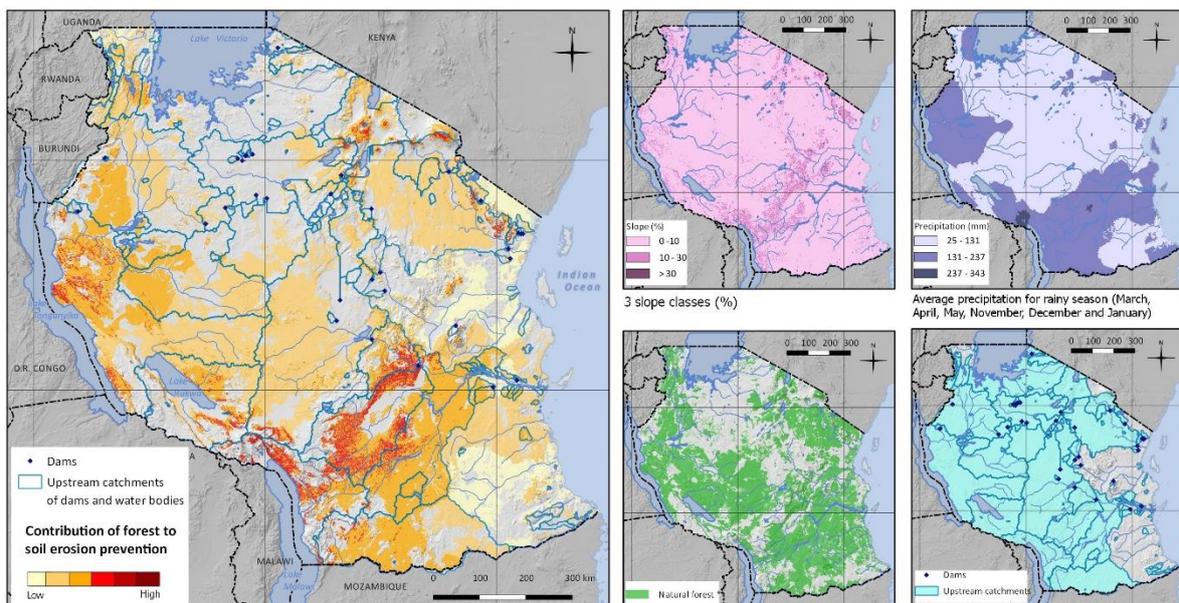
- Use a participatory approach, involving multiple stakeholders from different sectors, organizations and communities with local knowledge to identify drivers, barriers and the areas affected or at risk.
- Map current direct and indirect pressures on forest, examine their relationship with forest cover and forest-cover change, and explore how these may change in the future.
- Map areas that are likely to be affected by particular drivers or barriers in the future (e.g. planned deforestation due to the proposed development of infrastructure or changes to land-use designations).
- Map current areas where conservation, enhancement and sustainable management activities are already being undertaken and examine the relationship between factors that are either hindering or promoting their success.
- Map areas with physical, environmental, and socio-economic potential for the promotion of ‘plus’ activities.

Maps showing individual pressures/future threats layers and maps using simple overlays can be created, to show where different factors coincide. This does not ‘select’ particular areas, but these maps can be important inputs into multi-stakeholder workshops, where participants identify areas suitable for REDD+ interventions based on their expert and local knowledge.

Maps showing areas meeting certain criteria can also be created. For example, a map showing areas at risk of small-scale agricultural expansion may highlight areas based on the presence of existing agriculture, areas designated for future agriculture through the land-use plan, and socio-economic factors such as poverty and population.

This approach can be more subjective in terms of the criteria and thresholds used and needs to be validated by expert and local knowledge. If the knowledge needed to inform the workflow of the map is lacking, or the workflow is not properly validated, it can lead to misinformed use of data. Assumptions should be transparently presented so that planners and stakeholders understand the data that were used to create the map and how they influence the areas that were selected by the spatial analysis process. One way to do this is to show the input layers or assumptions as a series of maps in an annex, so it is clear how the areas were selected, what input layers were used and what criteria were applied. Alternatively, input maps can be presented alongside the final output, as in the example map below, where the input layers are presented on the right-hand side of the final output map.

This map shows areas where forests are particularly important for limiting soil erosion that might cause sedimentation problems for dams in Tanzania. The methodology is based on four parameters: slope, precipitation, locations of dams and water bodies and their catchments, and forest.



Map projection: WGS84 / UTM Zone 36S. Map prepared by Tanzanian Forest Service (TFS), UNEP-WCMC, FAO, Sokoine University of Agriculture (SUA) and Forestry Training Institute (FTI). Date: May 2013.

Data Sources:

Natural forest and water bodies: NAFORMA. 2013. NAFORMA land-use / land-cover Map 2010.

Dams: Dr. Mark Mulligan, Department of Geography, Kings College, London.

Slope: generated from Lehner, B., Verdin, K., Jarvis, A. 2008. New global hydrography derived from spaceborne elevation data. Eos, Transactions American Geophysical Union, 89 (10) (2008) 93-94. Journal Article.

Precipitation: Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. 2005. Jarvis. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25 (2005): 1965-1978. Journal Article.

* Defined according to the national forest definition to include the following land cover classes: montane and lowland forest, open and closed woodland, mangroves, thickets and bushlands.

3. Mapping REDD+ interventions to address a driver or barrier

Both participatory and spatial analysis approaches may play a role in mapping priority areas for the implementation of REDD+ interventions. During the Provincial REDD+ Action Plan (PRAP) development process in Viet Nam for example, both approaches were used, with workshop participants, first indicating areas for particular interventions, and spatial analysis teams conducting further analysis in GIS.

For the spatial analysis approach, two main steps are required:

1. **Defining the spatial logic or a workflow to answer a specified question.** The workflow will outline what datasets and geoprocessing tools needed to produce the desired output map. This workflow should also take into account a) the area affected by/at risk of the driver/barrier, and b) the results of the participatory mapping of interventions.
2. **Putting the workflow into QGIS Graphical Modeler.** By putting the geoprocessing steps into a single tool, the analysis can be run as a single step, or in fewer steps.

4. Defining spatial logic and creating a workflow (using a REDD+ intervention example)

Defining **workflows** helps you to think about **how you are going to undertake a piece of analysis**: the spatial logic, the technical GIS processes, and the sequence of steps.

This section of the tutorial focuses on the thinking and preparation required before building a workflow in QGIS Graphical Modeler. To help identify potential locations for a particular REDD+ intervention, a workflow would combine factors in multi-criteria analysis, so that we **include** areas **suitable** for the intervention and **exclude** areas that are **unsuitable**.

Considering the questions below can help to clarify the input layers, other data and processes you will need in your workflow:

- Where are the areas affected by/at risk from the drivers or barriers? The location of interventions should be informed by the location of drivers/barriers; this may be based on previous maps developed to show drivers/barriers, or on other knowledge about which areas are affected. This could be a large proportion of the land area, for example, all forest in a province may be affected by a barrier such as lack of monitoring resources.
- What physical aspects will affect the implementation of the intervention? For example, slope, soil type, forest type, climate.
- What other aspects may affect its feasibility? For example, accessibility of sites, carbon stocks, forest condition, or risks to the success of the intervention (e.g. fire risk)
- What is the potential to enhance benefits from the intervention? For example, can it contribute to poverty reduction, biodiversity conservation, or ecosystem services provision?
- What social and environmental risks are associated with the intervention? What is the potential to reduce risks and support safeguards, for example prevent the conversion of natural forest or reduce the risk of displacement (i.e. reducing the risk of moving deforestation or degradation to another area)?

In the example of Viet Nam, much relevant information should have been gathered during the PRAP process. For instance, previous analysis, and participatory mapping, of drivers and barriers can help identify the driver/barrier area. Meanwhile, the social and environmental risks and benefits assessment should help to identify the risks and benefits that could be associated with each intervention.

The identification of areas suitable for specific interventions can be complementary to, and used alongside, other participatory methods with stakeholder involvement. For example, if a participatory mapping approach has been undertaken to define potential areas, is any further analysis needed? This may vary between interventions. Participatory maps may give a broad picture, for example they may identify areas at the administrative unit level (e.g. the commune) and provide some of the criteria that could feed into a more detailed spatial analysis if required to complement the participatory results.

In defining the spatial logic to be used for the workflow, as a first step it is often useful to think about where **the REDD+ intervention cannot be undertaken**, to **exclude areas** where that REDD+ intervention would **not be possible**. It is often easier to do this before identifying **where the REDD+ intervention can be undertaken** in the remaining area.

When thinking about the spatial analysis to be undertaken, you will need to identify what criteria and data you will use to make those exclusions/inclusions, what geoprocessing tools you can use in QGIS, and whether the data are available (and available at an appropriate scale).

It is important to document the reasons why you are excluding or including certain areas and what factors have been used to determine these areas. This will help ensure that any analysis can be presented clearly and transparently to policy makers, so they can understand how a map has been created and what the assumptions are that have influenced it.

In this tutorial, an example workflow will be shown for the development of a REDD+ intervention layer for **community-based sustainable forestry to address the driver: small-scale conversion of forest to cassava**, on the basis that forests that are valued by the community are less likely to be converted to agricultural land.

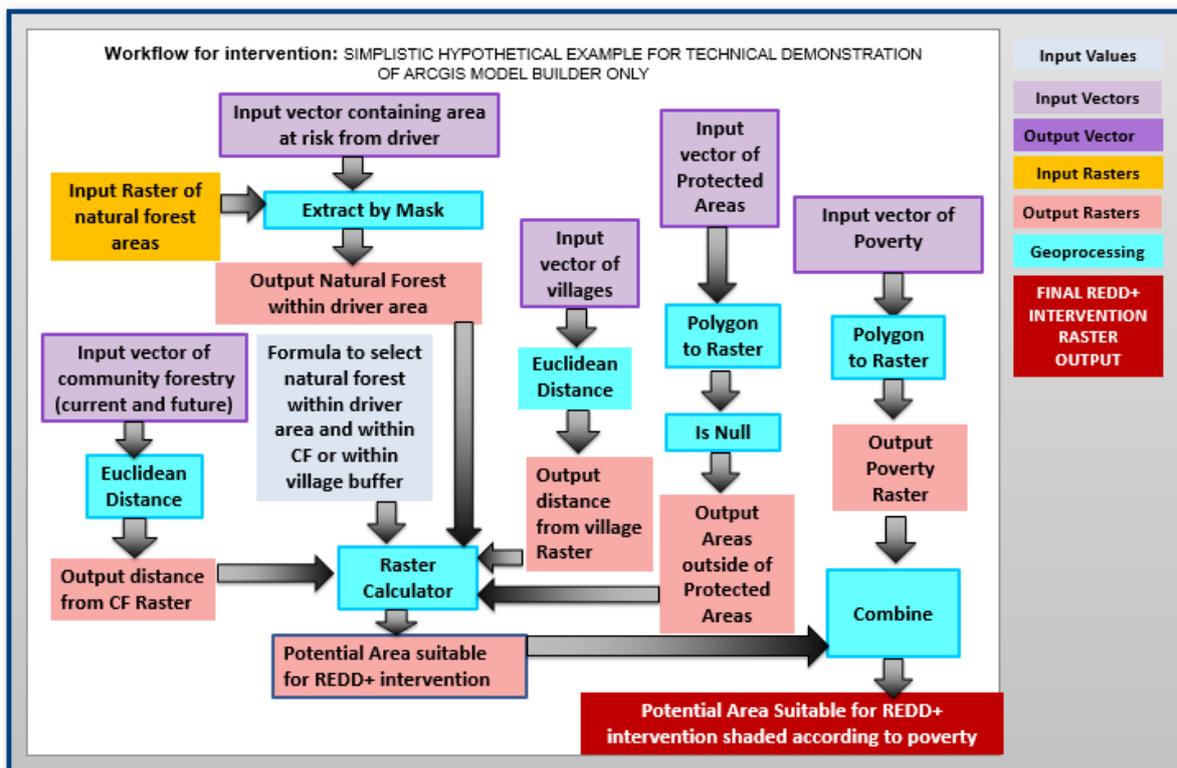
To help define a workflow for this question, we can consider the following questions:

- Where are the areas at risk from small-scale cassava expansion (now and in the future)?
- Where can community-based sustainable forestry feasibly occur? In our examples, areas close to villages are regarded as more feasible.
- Which forest area designations should be included? In our example, strictly protected areas are not available for community forestry.
- Should the intervention occur in natural forest and/or planted forest? In our example, natural forest is preferred.
- Should it be limited to existing community forestry areas or broader? In our example, areas close to existing or planned community forests are preferred.
- What benefits and risks are associated with the intervention? Can they be mapped? In our example, poverty alleviation was the only additional benefit considered.

The GIS analysis would then **exclude** areas not at risk from the driver, and areas where it is not possible to undertake that particular action, and **include** areas that are considered suitable, and where benefits could be enhanced and risks reduced. The table sets out the input layers for an example workflow:

Type of Input layer/data	How to use	Name of dataset in Mythical_Database folder
Forest cover	Natural forest area available for action	Natural_forest_mythical
Village locations	Areas near villages with likely demand for cassava production and/or community forestry (CF) activities	Village_mythical
Existing and potential community forests	Category of forest; areas already identified as current or likely CF sites	Community_forestry_mythical
Protected Areas	Exclude strictly protected areas	PA_mythical
Extent of driver	Area affected by / likely to be affected by driver (conversion to cassava) <i>(in this example a future Land Use Plan has been used to identify broad areas designated for agriculture)</i>	future_LUP_agriculture_mythical
Potential to alleviate poverty (as a benefit of the intervention)	Areas with medium-high poverty rates	Communes_mythical (using the field pov_hml , values: (1) low (2) medium and (3) high

The workflow can be hand-drawn in a flow diagram style prior to putting it into QGIS. In this example, we will use a workflow designed for ArcGIS to demonstrate how equivalent tools and analysis can be found and to adapt and implement the workflow in QGIS. The example for the above intervention is presented below.

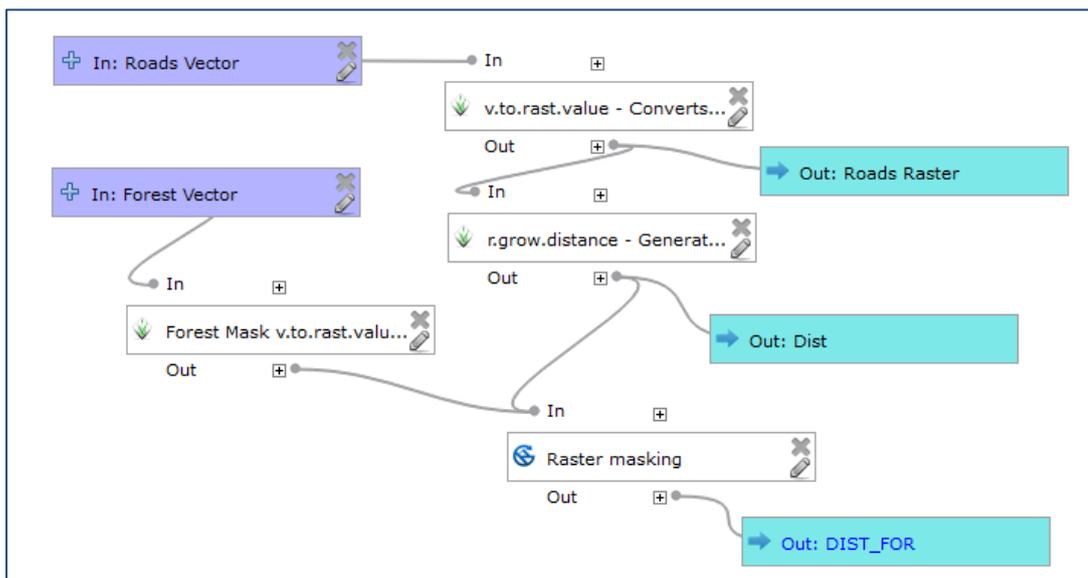


5. Using QGIS Graphical Modeler to implement workflows

5.1. Overview of Graphical Modeler

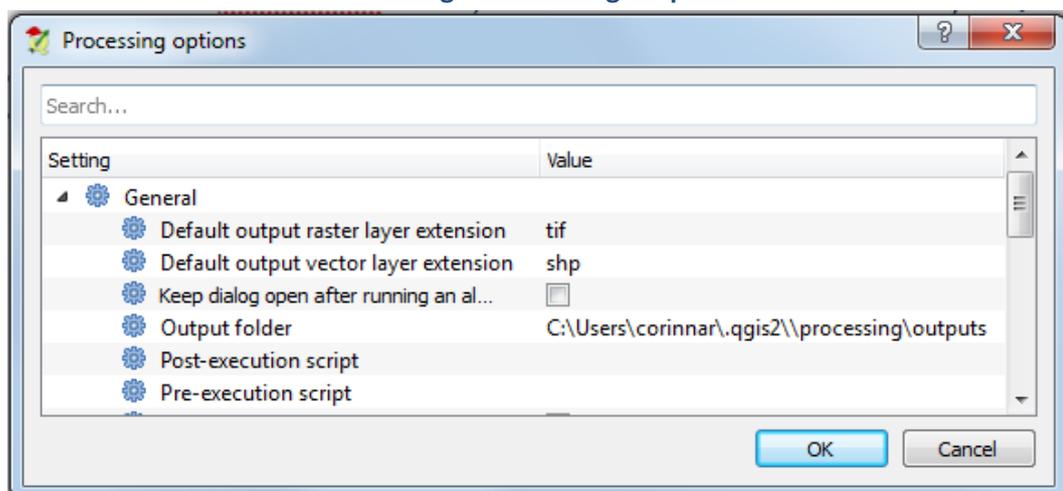
Graphical Modeler is an application that you can use to **create**, **edit**, and **manage models**. It is the equivalent to the ArcGIS Model Builder. Models in QGIS are workflows that string together sequences of geoprocessing tools, feeding the output of one tool into the next. Benefits of using the Graphical Modeler include better organization for improved workflows and faster analysis. By standardizing processes in this way, any future repeat analysis is also made much easier, enabling replication and direct comparison of results.

A simple model may only contain one or two steps and QGIS geoprocessing tools. For example, the model below classifies forest according to distance from roads:



5.2. Transferring a workflow into QGIS (using the REDD+ intervention example)

- a. Open **QGIS**
- b. From the main menu click **Processing >>Processing>>Options**



- c. The default output location for storing models is the **.qgis2** folder. You can change this if you wish to store them in an alternative location, **make a note of the location**. All your QGIS project models will be stored here.

- d. Click **OK** to close the window
- e. Copy the **MODEL_BUILDER_DEMO** folder onto your computer
- f. From the **MODEL_BUILDER_DEMO** folder open the project **Mythical_Model_Builder.qgs**
- g. Familiarize yourself with the data in the **Table of Contents** (left hand panel) in QGIS.

The example data that are used in this tutorial are stored in the folder **Mythical_Database**. The table below lists the data layers that are contained in the folder.

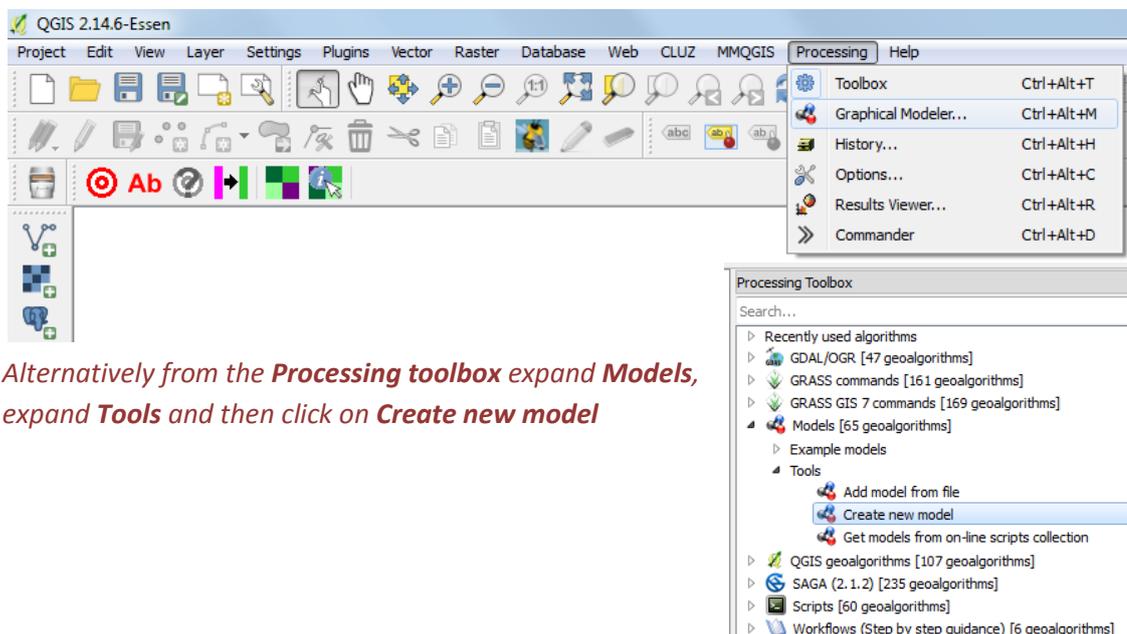
communes_mythical – Administrative boundaries (Communes)	community_forestry_mythical – Current and proposed community forestry sites
DEM_mythical – Digital Elevation model	district_mythical – Administrative boundaries (Districts)
future_LUP_agriculture_mythical – Future land use plan for Agriculture	HILL_mythical – Hillshade generated from Digital Elevation model
hydrobasins_mythical – Hydrological basins	hydropower_mythical – Planned and existing Hydroelectric sites
lakes_rivers_mythical – Water bodies and rivers	land_concess_mythical – Economic land concessions
landuse_mythical – Current landuse	market_mythical – Market locations
natural_forest_mythical – A subset of the current landuse layer that just contains the natural forest classes)	PA_mythical – Protected Areas
mining_concessions_mythical – Mining concessions	roads_mythical – Existing and planned roads
prod_for_mythical – Production forests	Poverty rate_mythical – Poverty rate by commune
village_mythical – Village locations	

Note: not all of these datasets will be used in the demonstration analysis, but they can be used as test data when developing other workflows.

5.3. Create a new Model in the Processing Toolbox

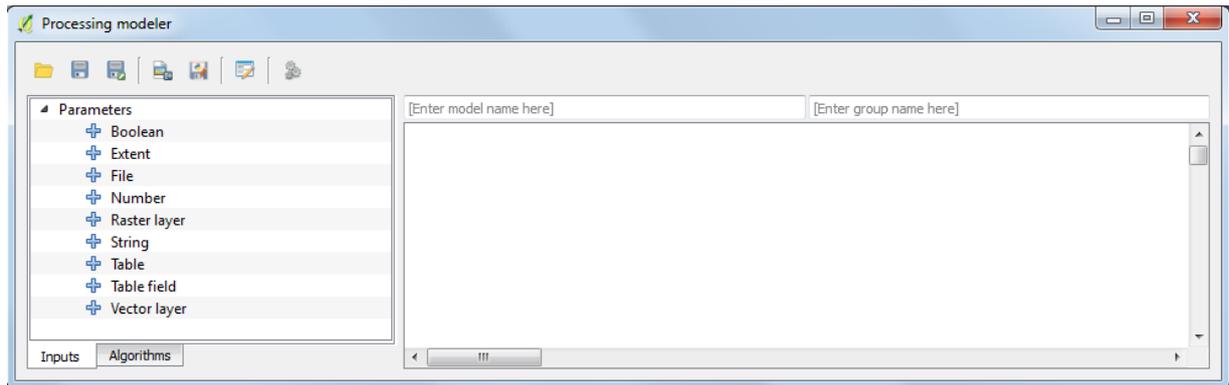
In QGIS models are stored in user defined groups. The group is specified at the time of creating a new model.

- a. To create a new model, from the main menu click on **Processing>>Graphical Modeler**



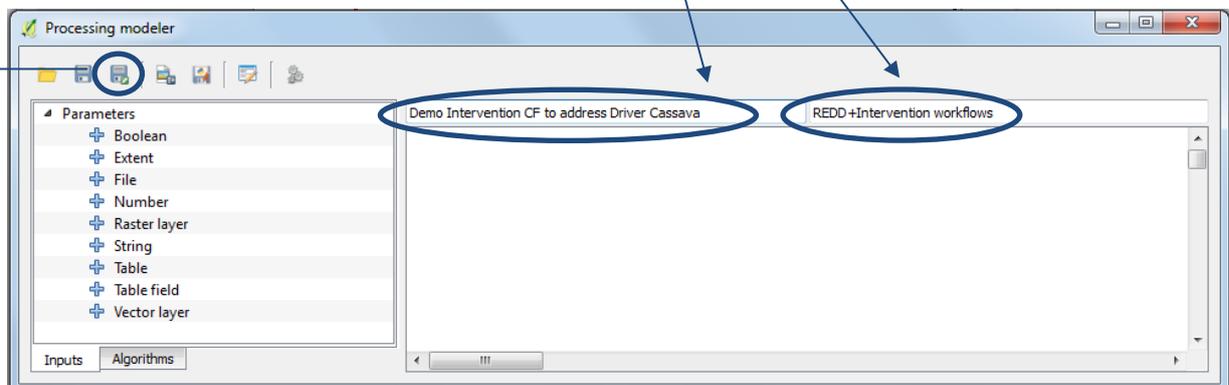
*Alternatively from the **Processing toolbox** expand **Models**, expand **Tools** and then click on **Create new model***

The **processing modeler** window appears.

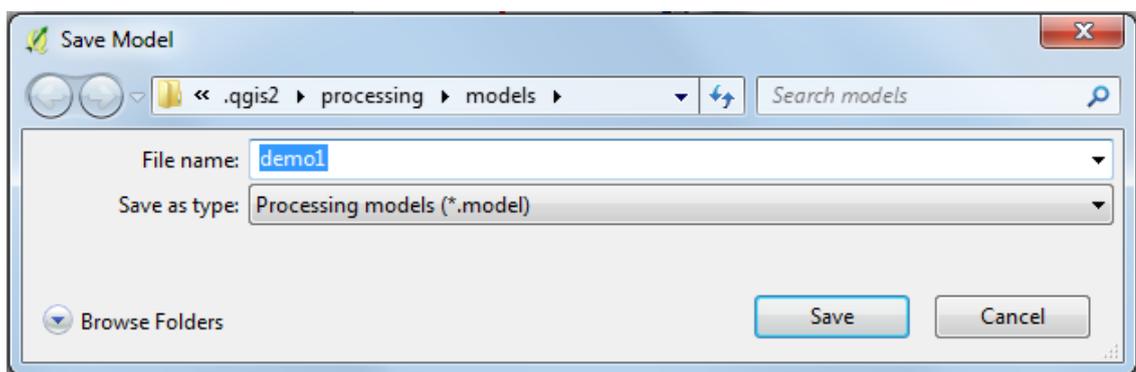


There are spaces at the top to specify the name of the model and the group to which it belongs. The group could contain models relating to a particular theme, or developed for a particular project for example

- a. Give the model a name e.g. **Demo Intervention CF to address Driver Cassava**
- b. Give the group a name, e.g. **REDD+Intervention workflows**

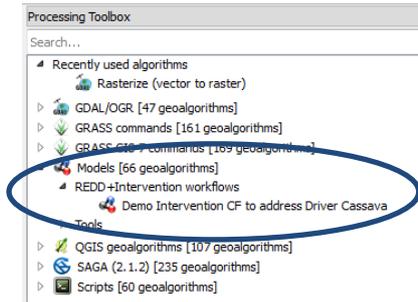


- c. Click on the **Save as** button and save the model. It will be stored in the default location unless you chose an alternative in Step 5.2b e.g. **C:\Users\xxxxxxxxxxx\.qgis2\processing\models**



- d. Click **Save**
- e. Close the model by clicking on the **cross** in the top right hand corner of the **processing modeler** window.

In the **Processing Toolbox** see that your new model group (**REDD+ Intervention workflows**) has appeared as a subset under **Models** and your new model within that set.



5.4. Adding the workflow to the model

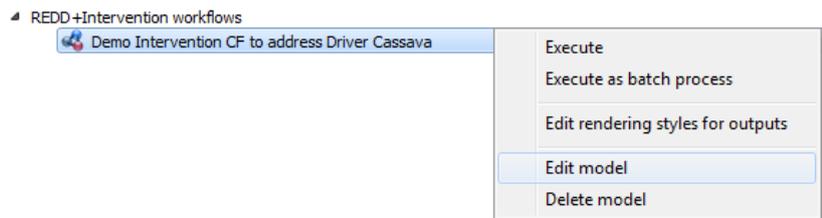
We will use the example workflow developed and described in **Section 4** to demonstrate this.

5.4.1. Add the first step to the tool – Select Natural forest within driver extent

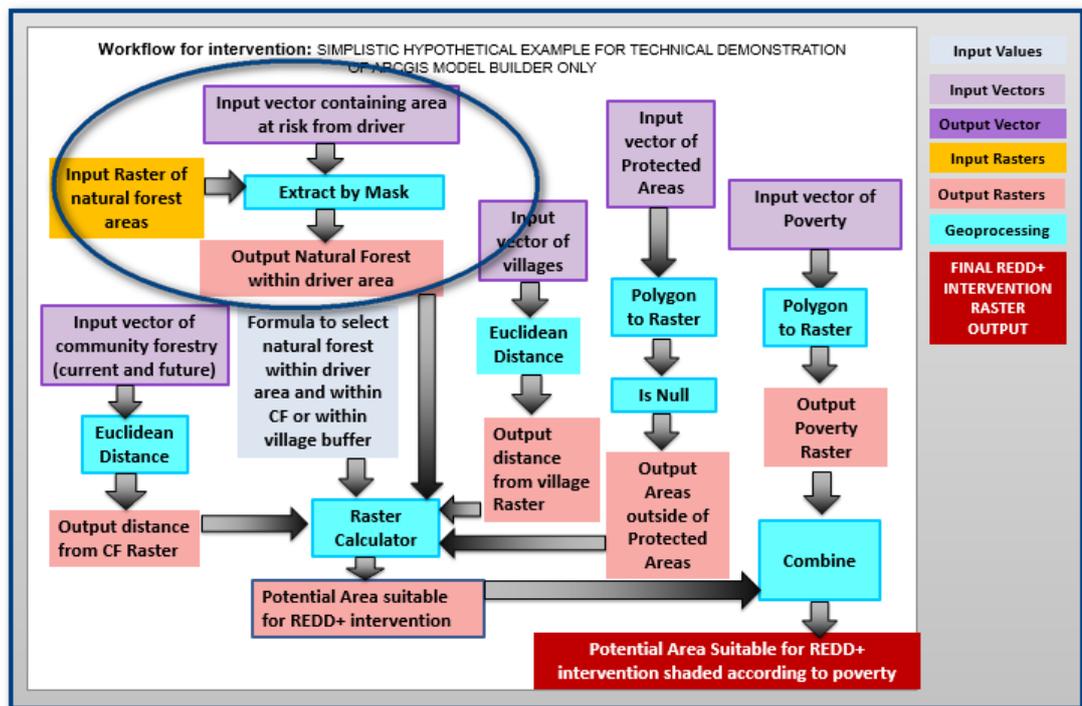
The first step is select the areas at risk from the driver* “conversion to cassava” and within those areas ensure that the intervention “Community Forestry” can only occur in natural forest areas.

(*Remember in this example a shapefile already exists for the driver area).

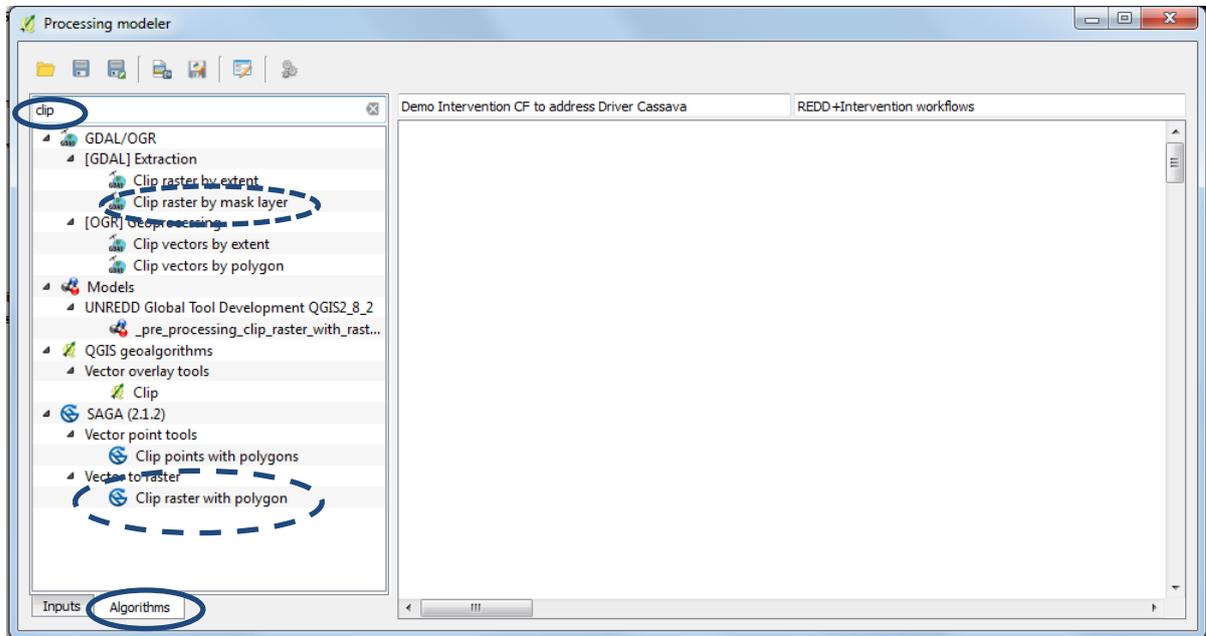
- a. In the **processing toolbox**, right-click on the model you created in the previous steps and click **Edit model**



Look at your planned workflow. For Step 1, we see an “Extract by Mask” function to clip out the **natural forest areas** within the **driver extent**.

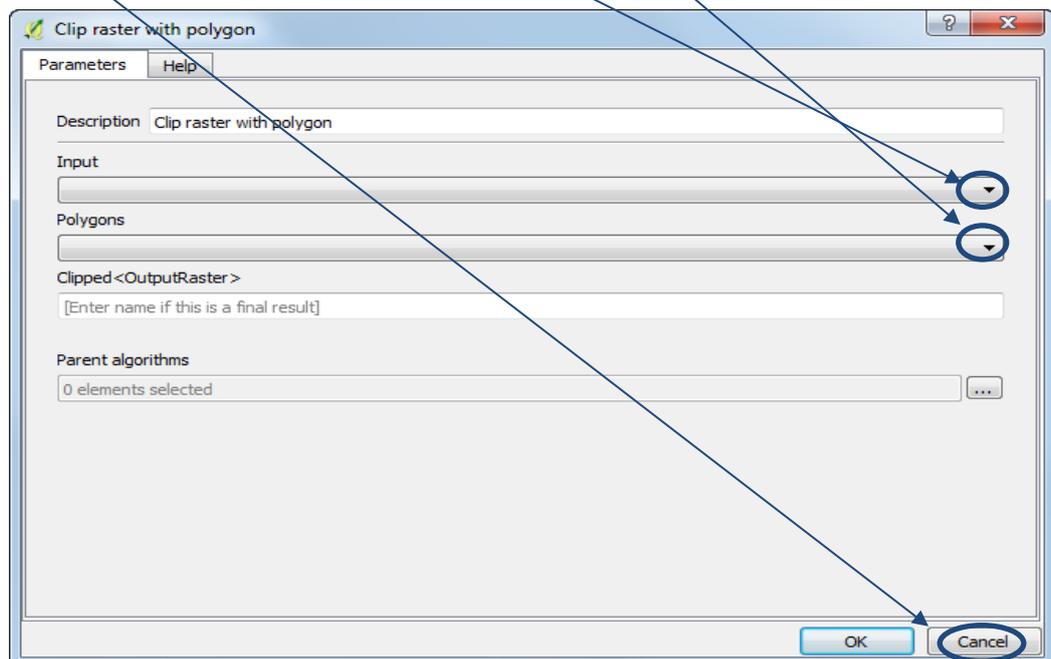


- b. Remember the workflow was designed to ArcGIS so the names of the tools may differ slightly. In QGIS if we click on the **Algorithms** tab and search for **Extract** we find there is no geoprocessing tool called **Extract by mask** but if we search for **clip** we see that there are two tools that could undertake a similar function **Clip raster by mask layer (GDAL)** and **Clip raster with polygons (SAGA)**.
- c. Either of these tools should enable us to extract an area of interest but for this example we will choose to use the **SAGA** tool. Double-click on the **Clip raster with polygon tool**.

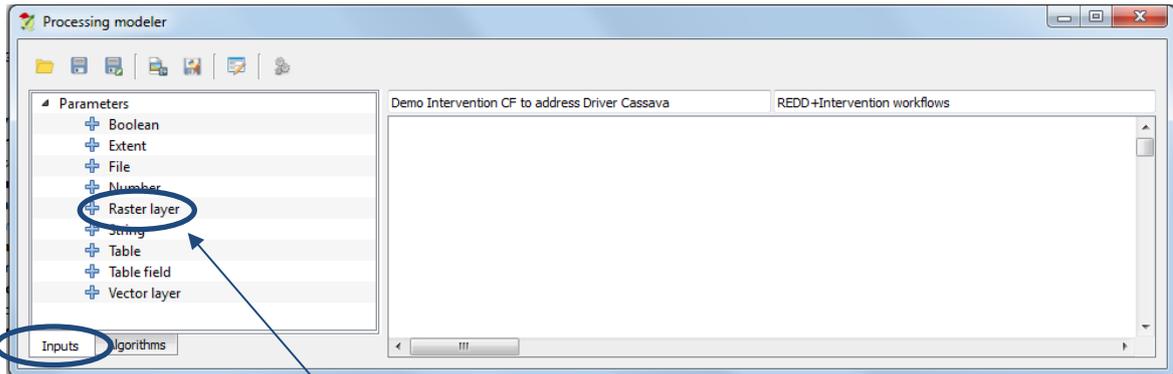


A window pops up which looks very similar to the dialog box when you run the tool directly from the processing toolbox.

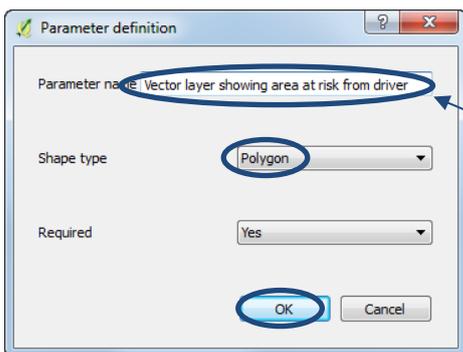
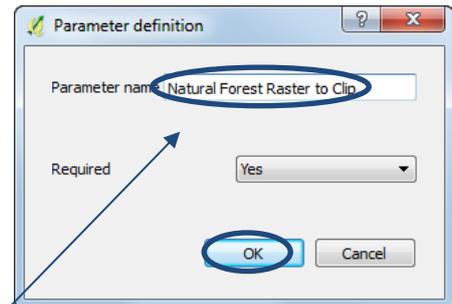
- d. Try to selecting an **Input** (raster) and a **Polygons** (layer to clip with). It does not let you select anything because you need to set these up in your model as **Inputs** to the **Clip raster with polygon tool**.
- e. Click **Cancel** to return to the **graphical modeler** window.



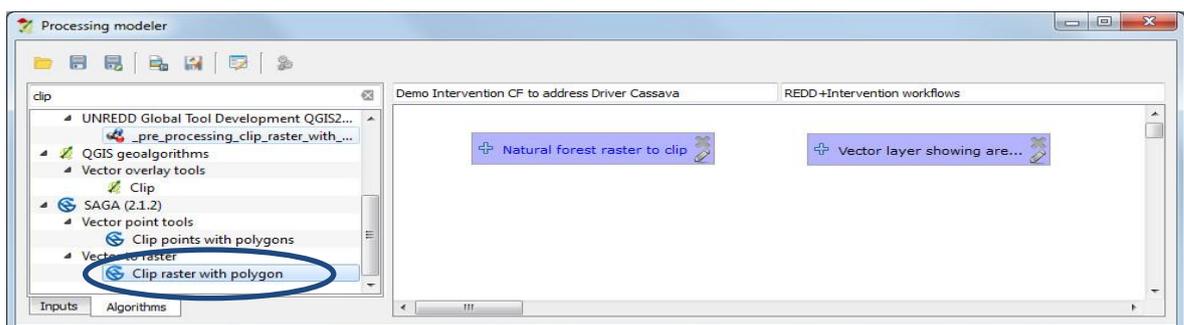
f. Click on the **Inputs** tab



- g. Double-click on **Raster layer** in the list of parameter.
- h. Give the parameter a name (This is the name that will appear on your model dialog screen when you run the tool. In this example type **Natural Forest Raster to Clip**. The dataset is required by the tool so leave **Required** set to **Yes**).
- i. Click **OK** and the Raster Parameter is added to the model canvas.



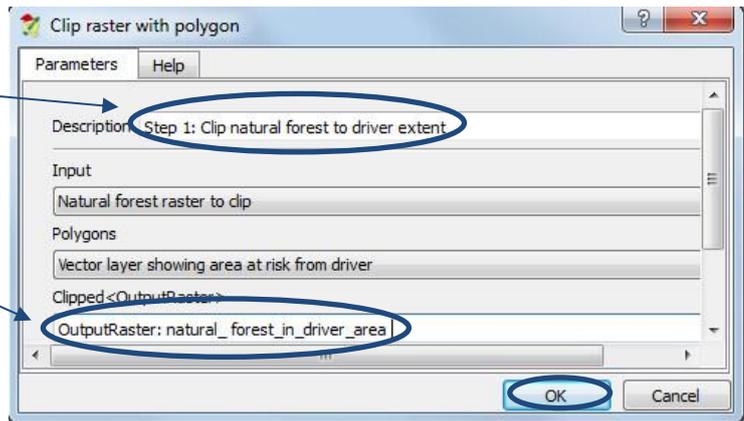
- j. Double-click on **Vector layer** add another parameter (i.e. the polygon layer to use as the clipping mask)
- k. Give the parameter a name. In this example type **Vector layer showing area at risk from driver**
- l. Change the Shape type to **Polygon**
- m. Leave **Required** set to **Yes**
- n. Click **OK** and the Vector Parameter is added to the model canvas.
- o. Click on the **Algorithms** tab again and double-click on the **Clip raster with polygon tool**.



p. Change the description e.g. to **Step 1: Clip natural forest to driver extent**

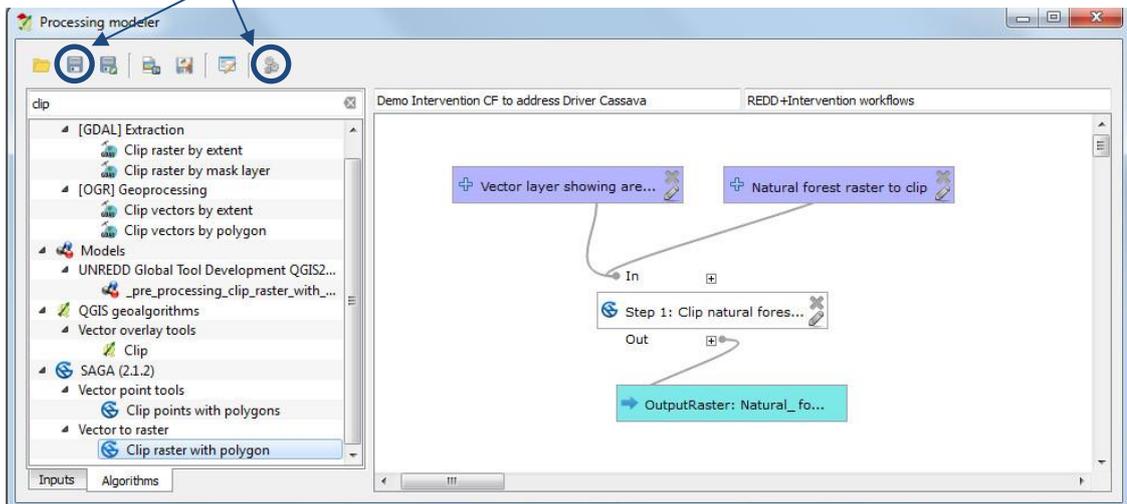
q. Type in a name for the output parameter value e.g. **OutputRaster: natural_forest_in_driver_area**

r. QGIS automatically picks up the **Input** and **Polygons** parameters and it guesses correctly this time because so far there is only one vector and only one raster parameter in the model. Click **OK**

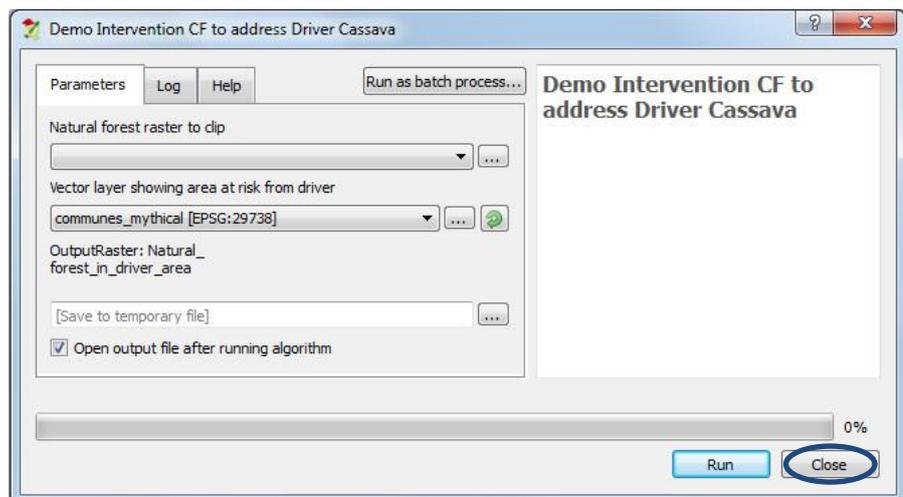


s. The first step now looks complete, click the **Save** button to save the model.

t. Click the **Run model** button to test the model so far. We immediately find a problem for our planned workflow - our natural forest layer is a vector dataset and the model requires a raster. Therefore we need to add a new step to the beginning of our model to convert the natural forest vector to raster.

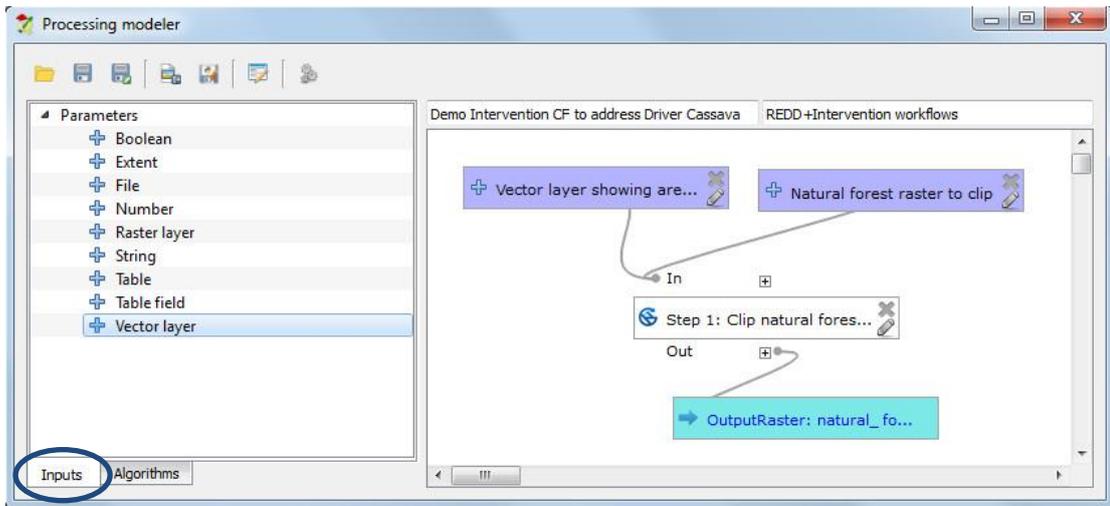


u. Click **Close** to close your tool. This returns you to the **Graphical Modeler**

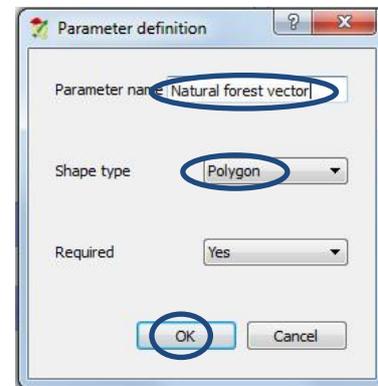


5.4.2. Modify the first step

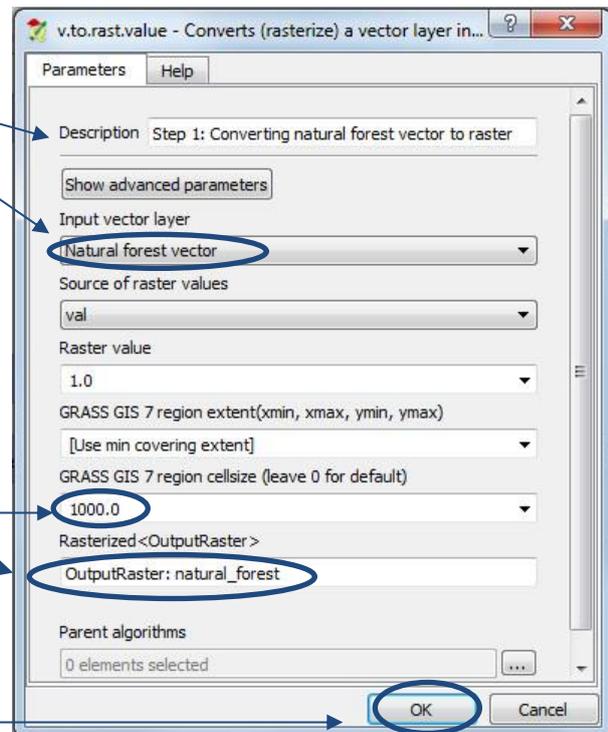
- a. We need to add a vector layer to the **Processing modeler** canvas which we will convert to raster, click in **Inputs** and select **Vector layer** and drag it onto the model canvas.



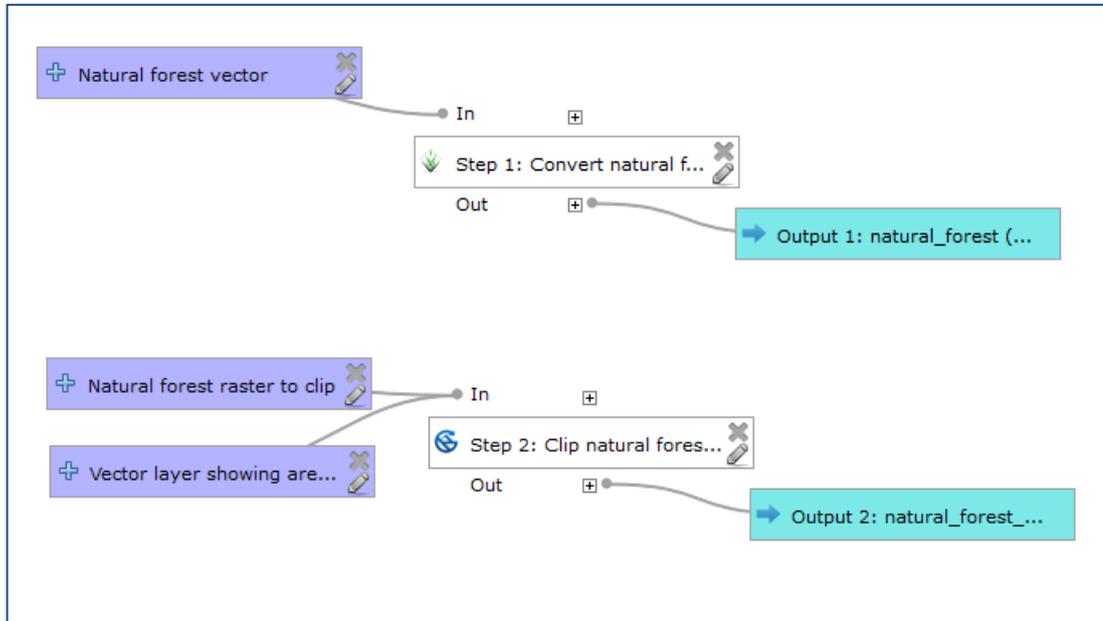
- b. Type in **Natural forest vector** in the **parameter name** box
- c. Set **shape type** to **Polygon**
- d. Click **OK**
- e. In the **Processing modeller**, click on the **Algorithms** tab and search for **v.to.rast**
- f. Select the **v.to.rast.value** tool and drag it onto the model canvas.



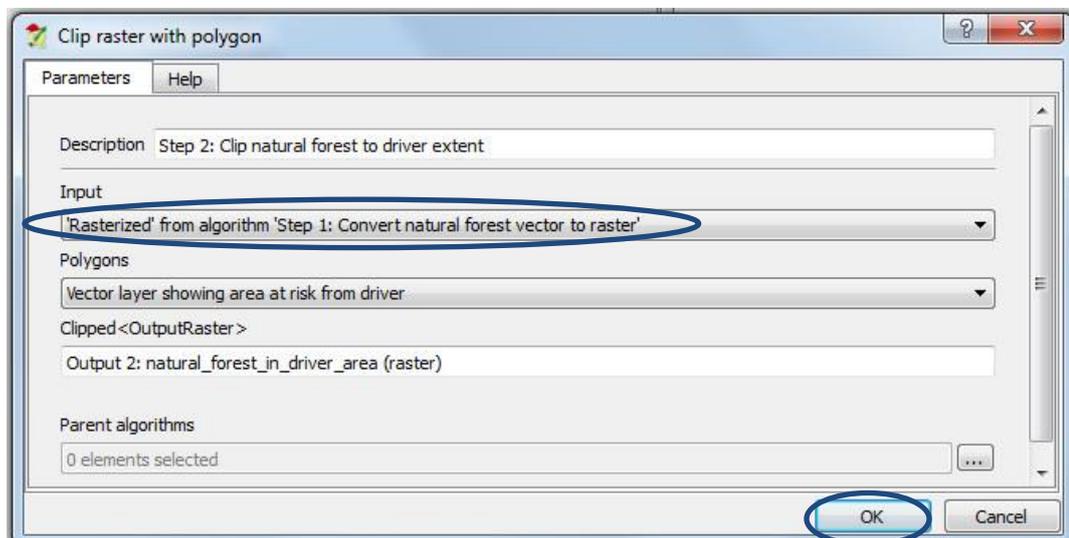
- g. Change the **description** to **Step 1: Converting natural forest vector to raster**
- h. For the **input vector layer** select the parameter **Natural forest vector**
- i. Set the **cellsize** to the size that you want to use for the analysis e.g. in this example **1000**
- j. Type in a name for the output parameter value **Rasterized <OutputRaster>** e.g. **OutputRaster: natural_forest**.
- k. Click **OK**



You can move the elements around on the model canvas so that you can see them clearly (as in the screen grab below). Once you have moved them you will see that there are currently two distinct parts that are not yet linked together. To link them, the output from the first step will now replace the Natural Forest raster input in the second step. Notice you also you will need to change the name of the second step to Step 2.

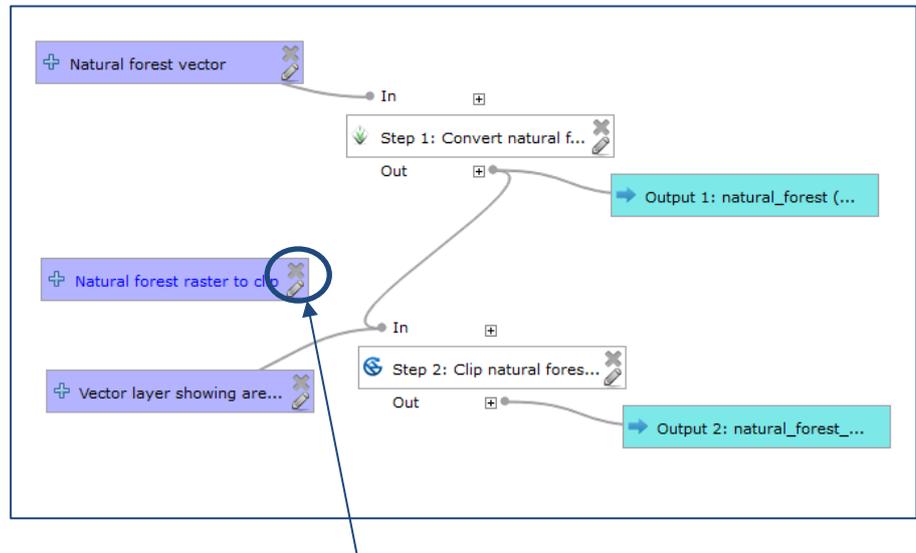


- l. Right click on the tool **Step 1: Clip natural forest to driver extent** and click **edit**
- m. Change the **description** so that it now says **Step 2: Clip natural forest to driver extent**
- n. Change the Input to **'Rasterized' from algorithm 'Step1: Convert natural forest vector to raster'** to pick up the output from the first step.



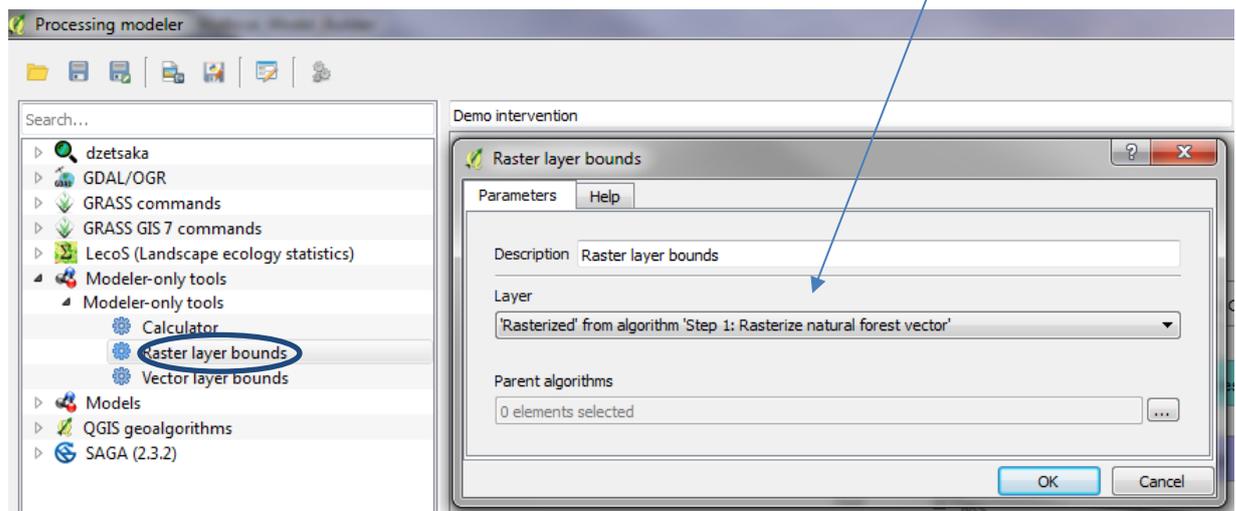
- o. Click **OK**

The old Natural Forest Raster has been disconnected from the rest of the model as it is no longer required. The natural forest raster produced from Step 1 is now an input to Step 2.



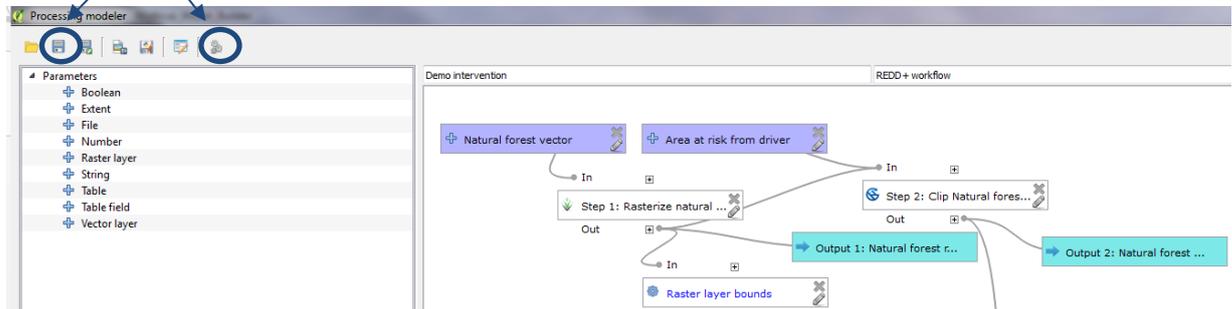
5.4.3. Setting the extent of the Raster layers

We need to set the extent of the raster layer so that all the outputs will have the same extent and no issues to the calculation will arise. To do so click on the “Modeler-only tools” in the algorithms panel and then select “Raster layer bound”. Choose as layer the one created in Step 1.



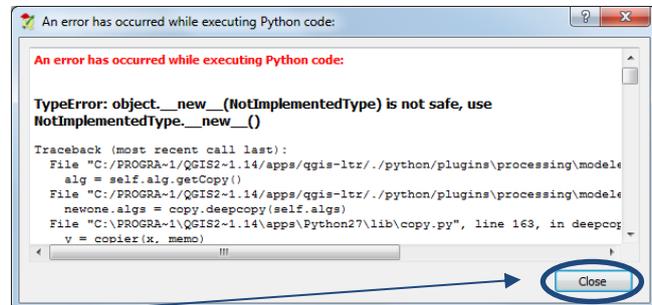
This will be the extent to be chosen in each of the following calculations.

- p. To remove the redundant parameter click the **X** in the top right hand corner.
- q. Click the **Save** button to save the model.
- r. The tool should now look like the one below. To test running the model you can press the **Run model** button



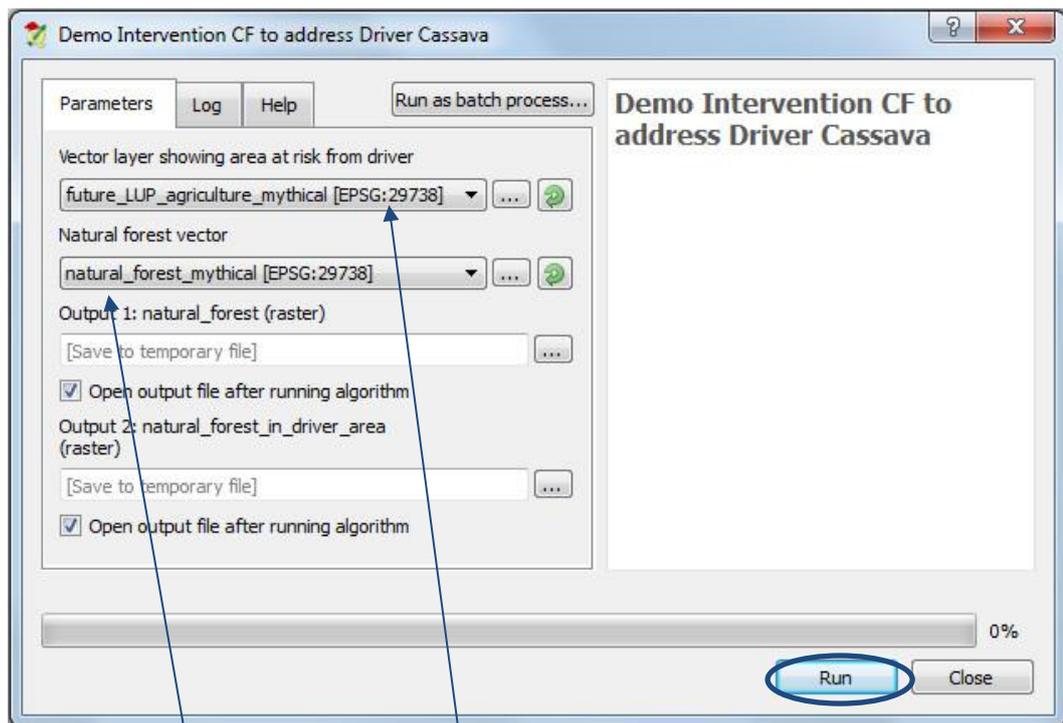
*Please note: we have found that sometimes testing the model in the **Processing modeler** window gives an error but the model runs fine if you run it from the **Processing toolbox**.*

*If your model opened then skip steps **s** and **t** below.*



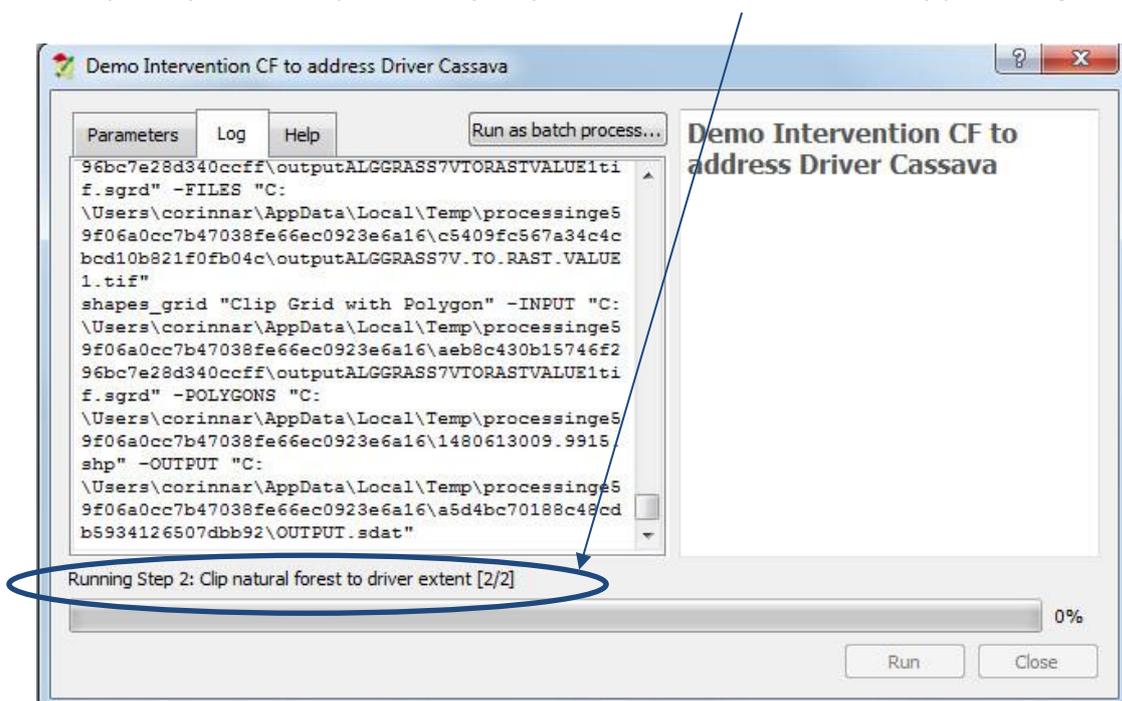
- s. If an error occurred click **Close** on the error message window and then click on the **X** in the top right to close the **Processing modeler** window.
- t. Then from the **Processing Toolbox** expand your **REDD+ Intervention workflows** group and double click on your model **Demo Intervention CF to address Driver Cassava**.

Upon opening, your model dialog should look like this:

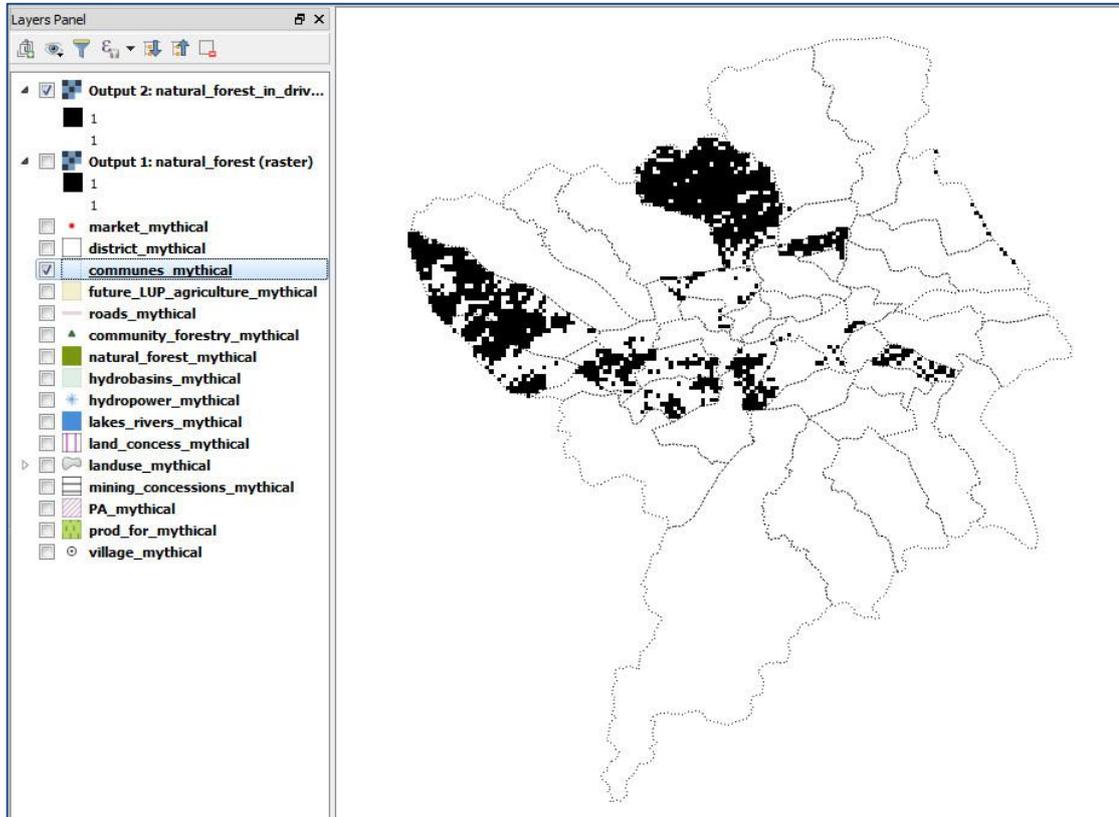
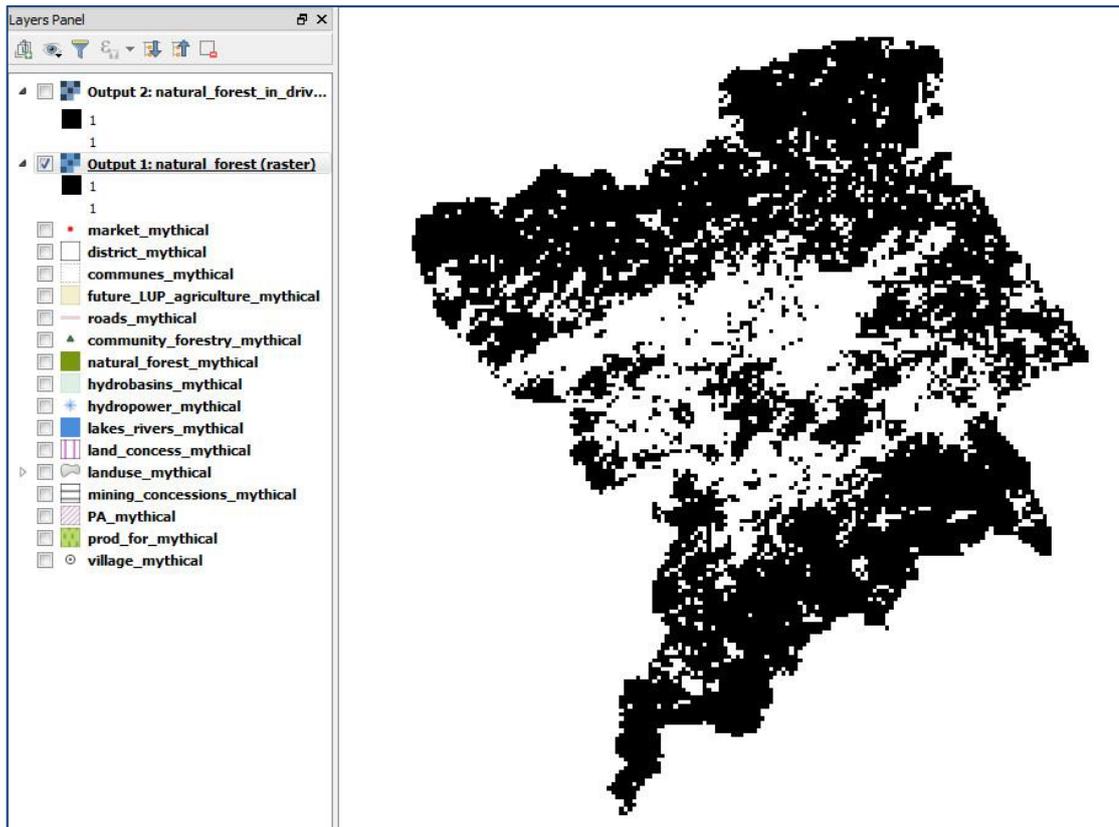


- u. For our example model, chose the **future_LUP_agriculture_mythical** as the **Vector layer showing area at risk from driver**.
- v. Choose the **natural_forest_mythical** as the **Natural forest vector**
- w. While we are still testing the model leave the two outputs as **[Save to temporary file]**
Click **Run** to run the model

The model should run successful and automatically close when it is complete. You can see progress. The example screen grab below shows Step 1 has been run and the model is currently running Step 2. The descriptions you entered provide useful information about what is currently processing.

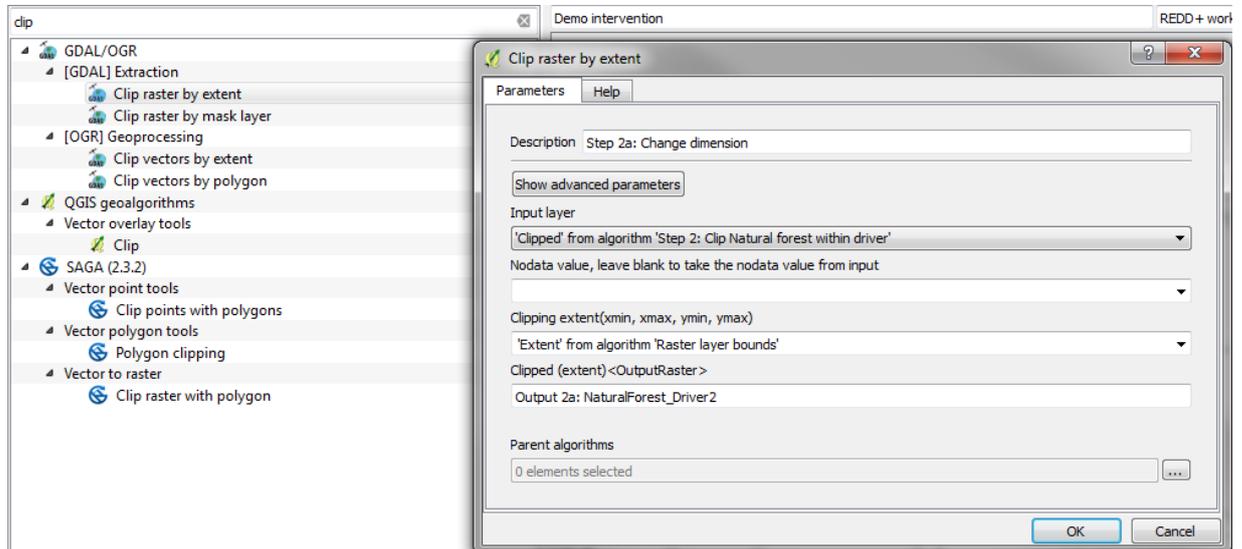


Once the processing is complete the outputs are added to the table of contents as below:



Important: since the algorithm used in step 2 doesn't allow to set the extent to be sure the extent of all the outputs are the same we need to add an extra step as described below.

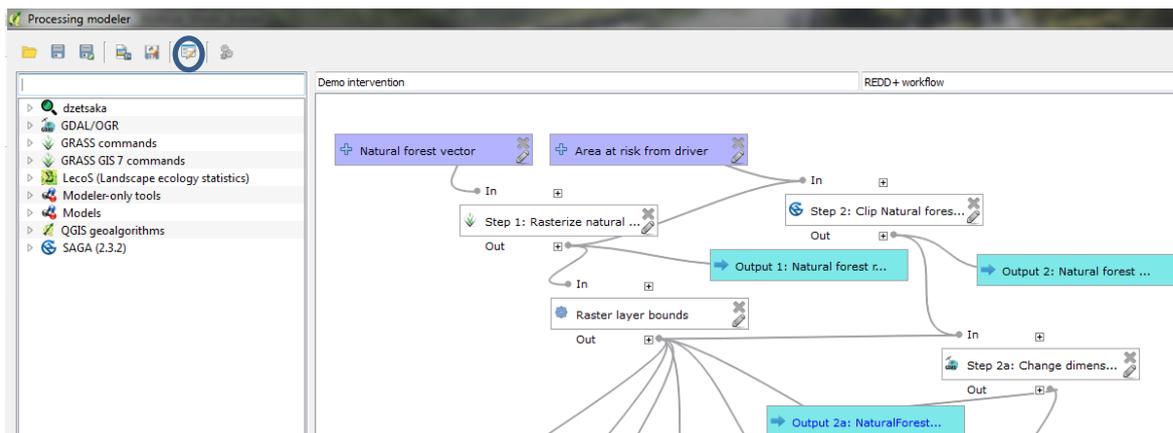
- In the algorithm panel select “Clip raster by extent”.
- In the description write Step 2a: Change dimension.
- As Input layer: “Clipped” from algorithm “Step 2: Clip natural forest within driver”
- As Clipping extent: “Extent” from algorithm “Raster layer bounds”
- As Output Raster, “Output 2a: NaturalForest_Driver2”



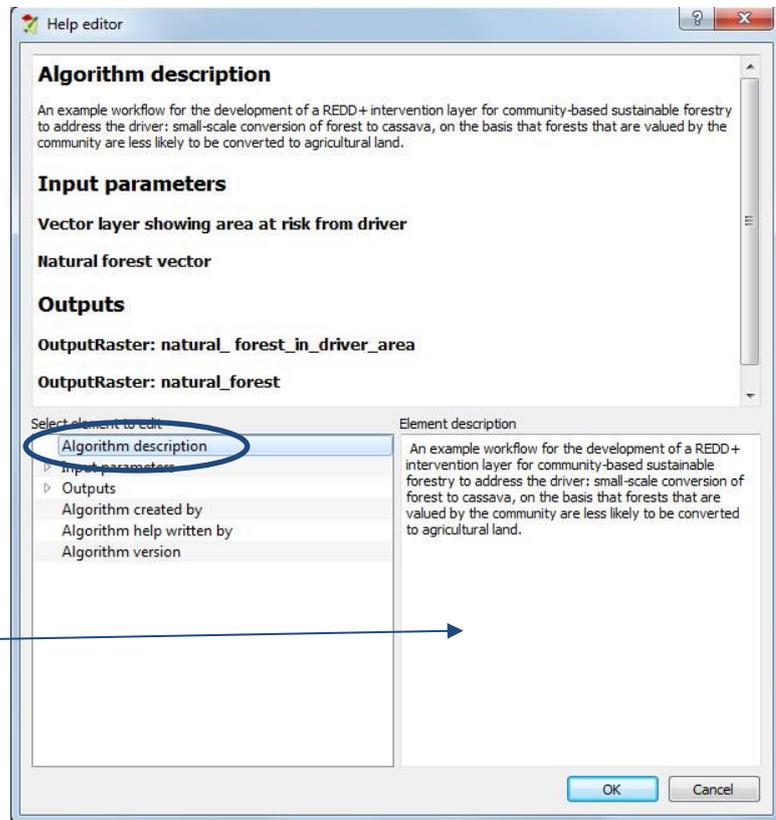
5.4.4. Document the first step

It is helpful to start adding metadata to the model at this stage to help you keep track of the different steps, their inputs and outputs. The metadata appears on the tool dialogue so it makes it more user-friendly for the person running your model.

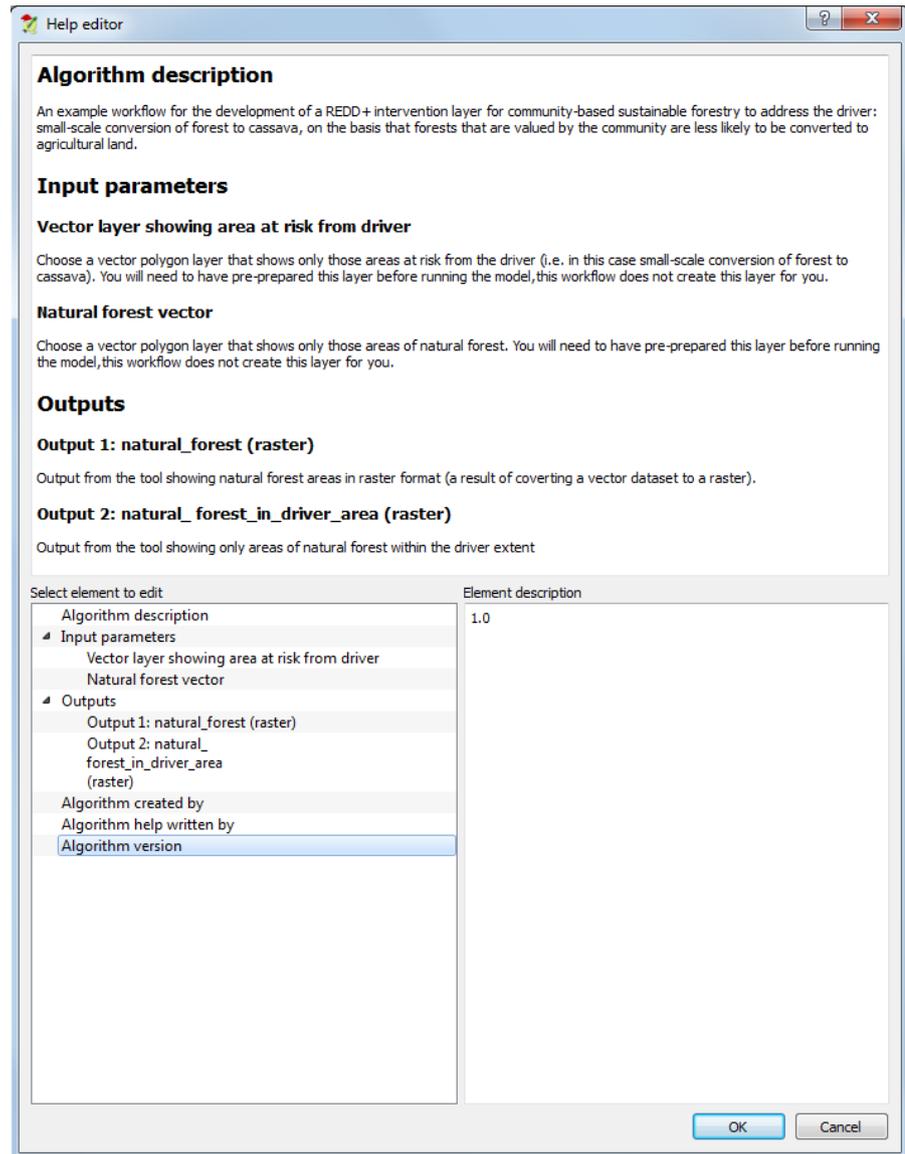
- If you closed your model, right click on your model in the **Processing toolbox** and click **Edit model** to re-open it in the **Graphical modeler**



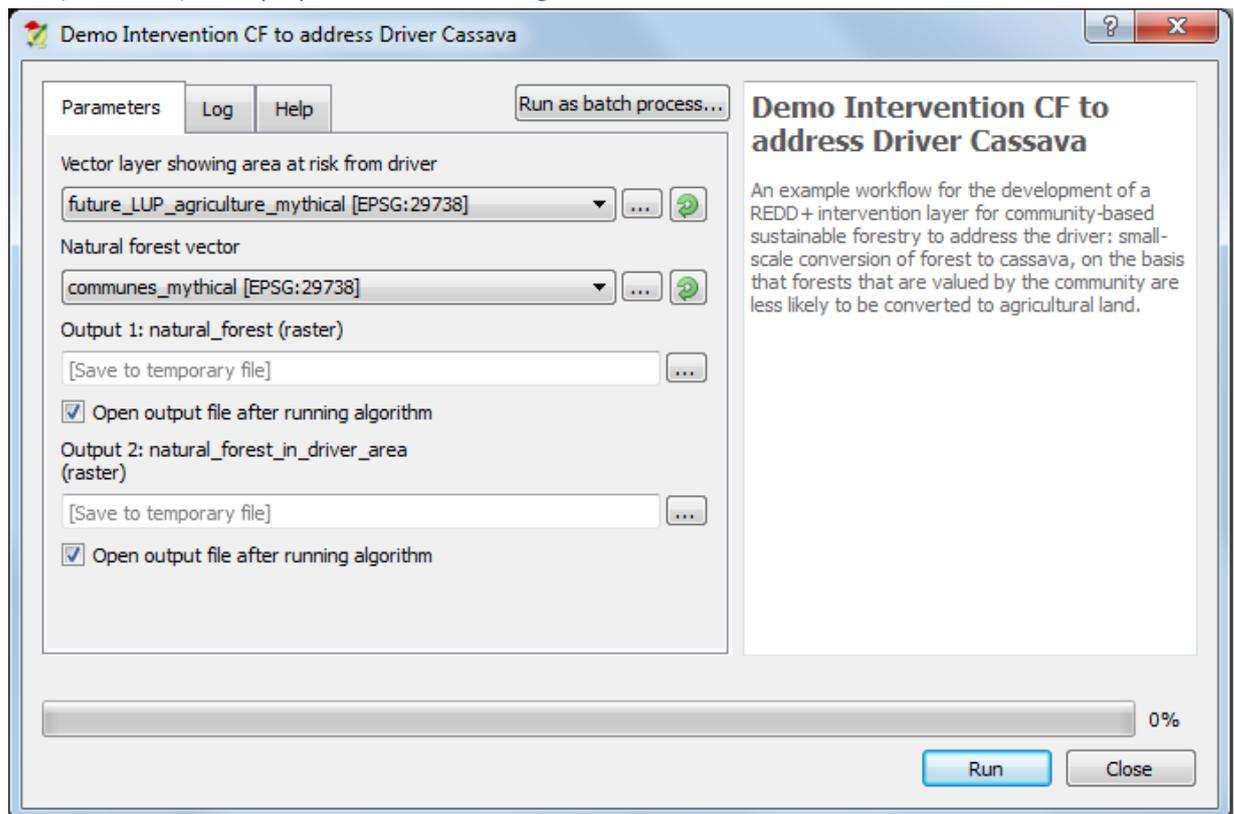
- b. Click on the **Edit model help** button in the **Processing modeler** window
The Help editor window appears. In the bottom left hand panel you select element to edit.
- c. First, click on **Algorithm description**
- d. In the **element description** panel, describe the purpose of your model (the whole model not just the first steps you have added). For our example, type **An example workflow for the development of a REDD+ intervention layer for community-based sustainable forestry to address the driver: small-scale conversion of forest to cassava, on the basis that forests that are valued by the community are less likely to be converted to agricultural land.**
- e. Click on the arrow to expand the **input parameters**
- f. Click on **Vector layer showing area at risk from driver** and type in the following element description: **Choose a vector polygon layer that shows only those areas at risk from the driver (i.e. in this case small-scale conversion of forest to cassava). You will need to have pre-prepared this layer before running the model, this workflow does not create this layer for you.**
- g. Click on **Natural forest vector** and type in the following element description: **Choose a vector polygon layer that shows only those areas of natural forest. You will need to have pre-prepared this layer before running the model, this workflow does not create this layer for you.**
- h. Click on the arrow to expand the **outputs**
- i. Click on **Output 1: Natural forest (raster)** and type the following description: **Output from the tool showing natural forest areas in raster format (a result of converting a vector dataset to a raster).**
- j. Click on **Output 2: Natural_forest_in_driver_area (raster)** and type the following description: **Output from the tool showing only areas of natural forest within the driver extent**
- k. Click on **Algorithm created by** and type e.g. **your name**
- l. Click on **Algorithm help written by** and type e.g. **your name**



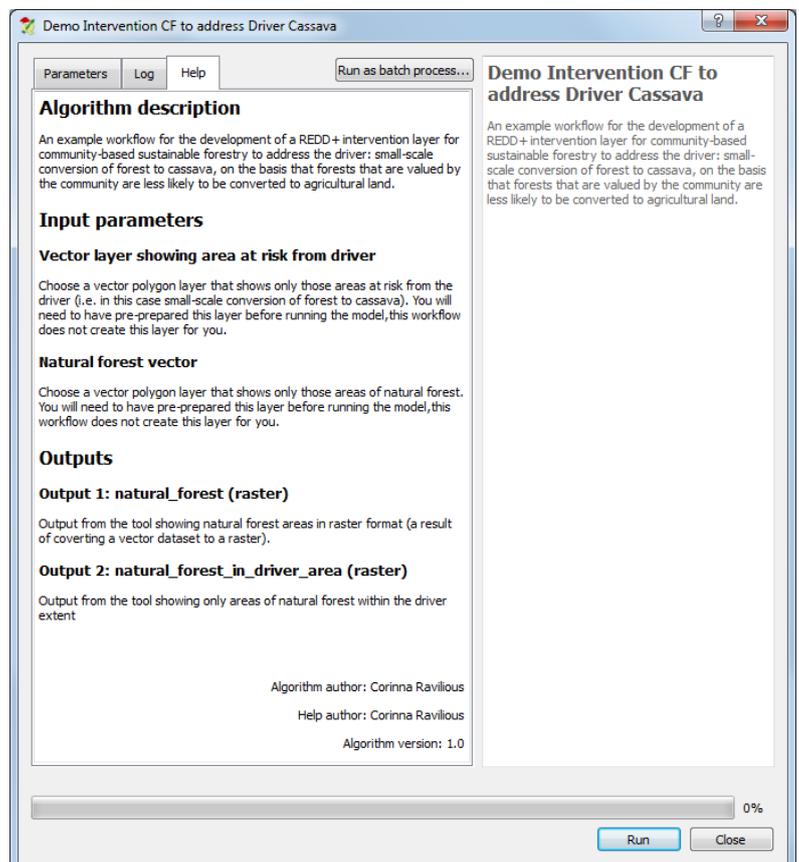
- m. Click on **Algorithm version** and type a version number e.g. **1.0**
- n. Click **OK** to close the help
- o. Click the **Save** button on the **Processing modeler** window to save your model and the newly added help



- p. Click the **Run model** button and see that your **algorithm description** (purpose of the model (workflow) is displayed in the tool dialogue



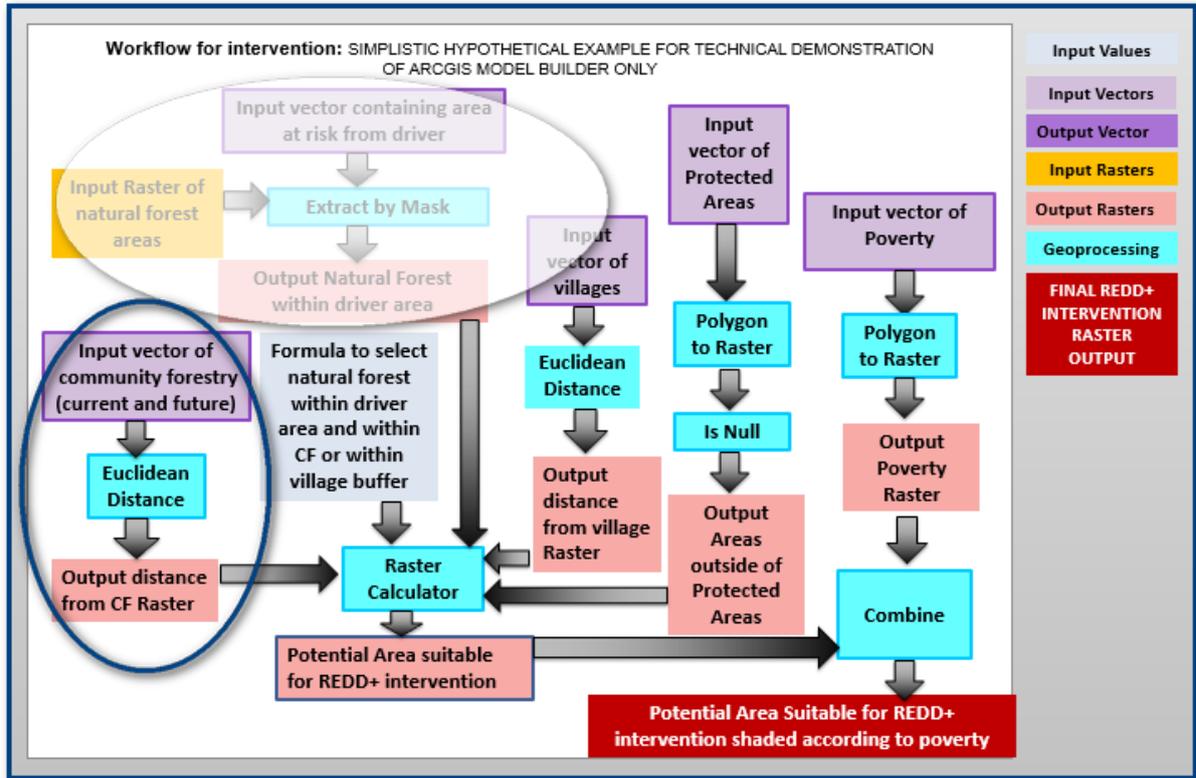
- q. Click the **Help** tab and see your help text you displayed in the tool dialogue



5.4.5. Adding the remaining steps of the workflow

5.4.5.1. Distance to community Forestry sites

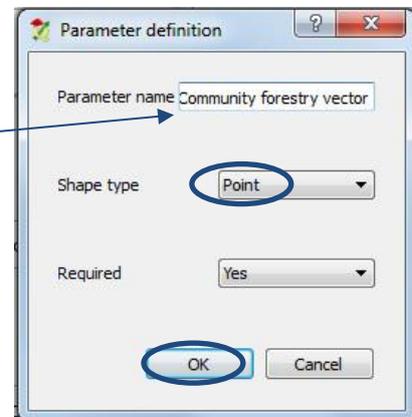
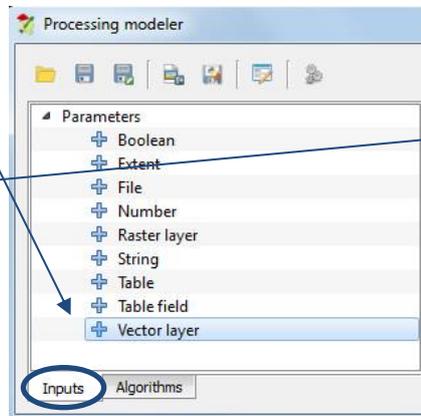
Look at your workflow design again to see what the next step is to add to the **Graphical modeler**. There is a **Euclidean Distance** function specified on the left. This will generate an output distance raster to the community forest sites Raster.

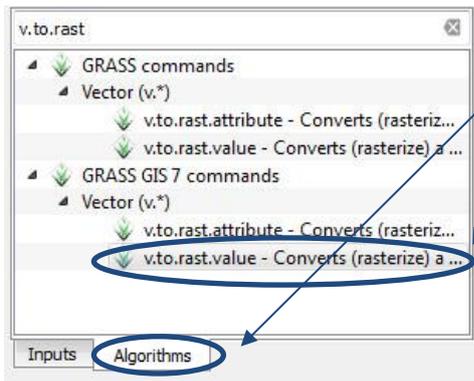


In QGIS the **Euclidean distance** can be generated by a variety of tools **Proximity (raster distance) (GDAL)**, **Proximity raster (SAGA)** or **r.grow.distance (GRASS)**. In this example we have chosen to use the **r.grow.distance** tool.

We want to generate a surface of distance to community forestry areas so that is the input dataset. Note, however, that the **r.grow.region** tool expects a raster layer, so again prior to adding the **r.grow.distance** tool we need to use the **v.to.raster.value** tool to convert the community forestry polygons to raster.

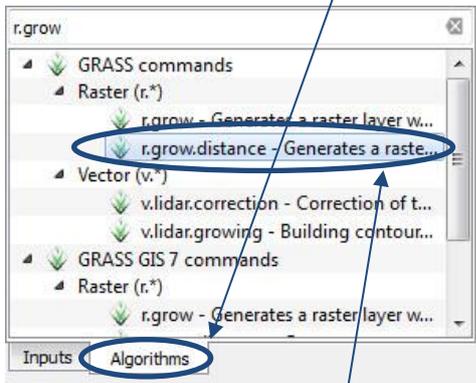
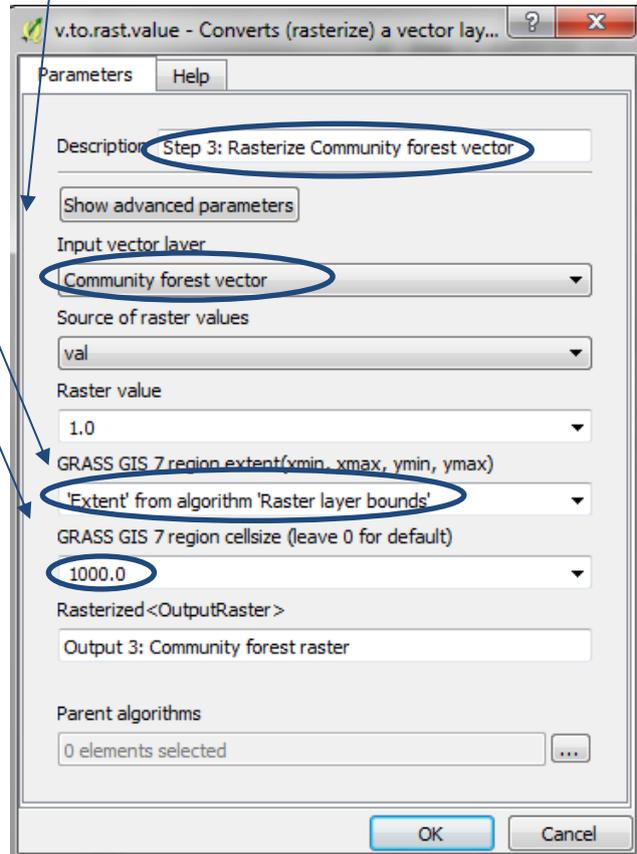
- Click on the **Inputs** tab add a **Vector Layer** and
- Type the **Parameter name** e.g. **Community forestry vector**
- Change the **shape type** to **point**
- Click **OK**



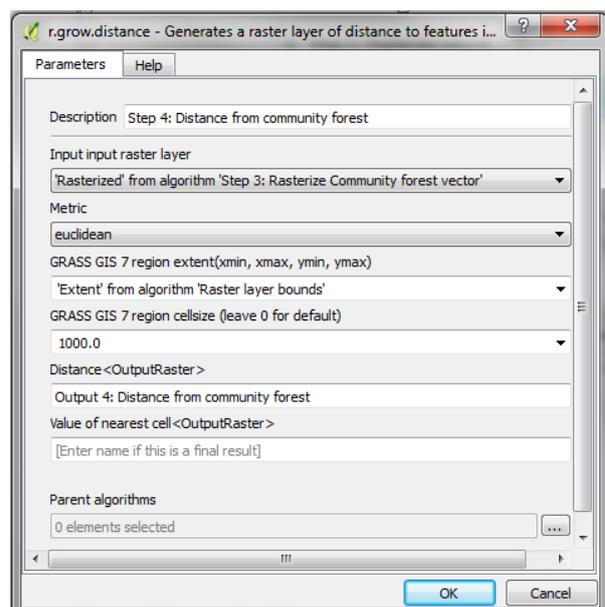


- e. Click on the **Algorithms** tab, search for **v.to.rast**
- f. Double click to add the **v.rast.value** tool
- g. Change the description to **Step 3: Convert community forestry vector to raster**
- h. Select the **Community forestry vector** as the **Input vector layer**

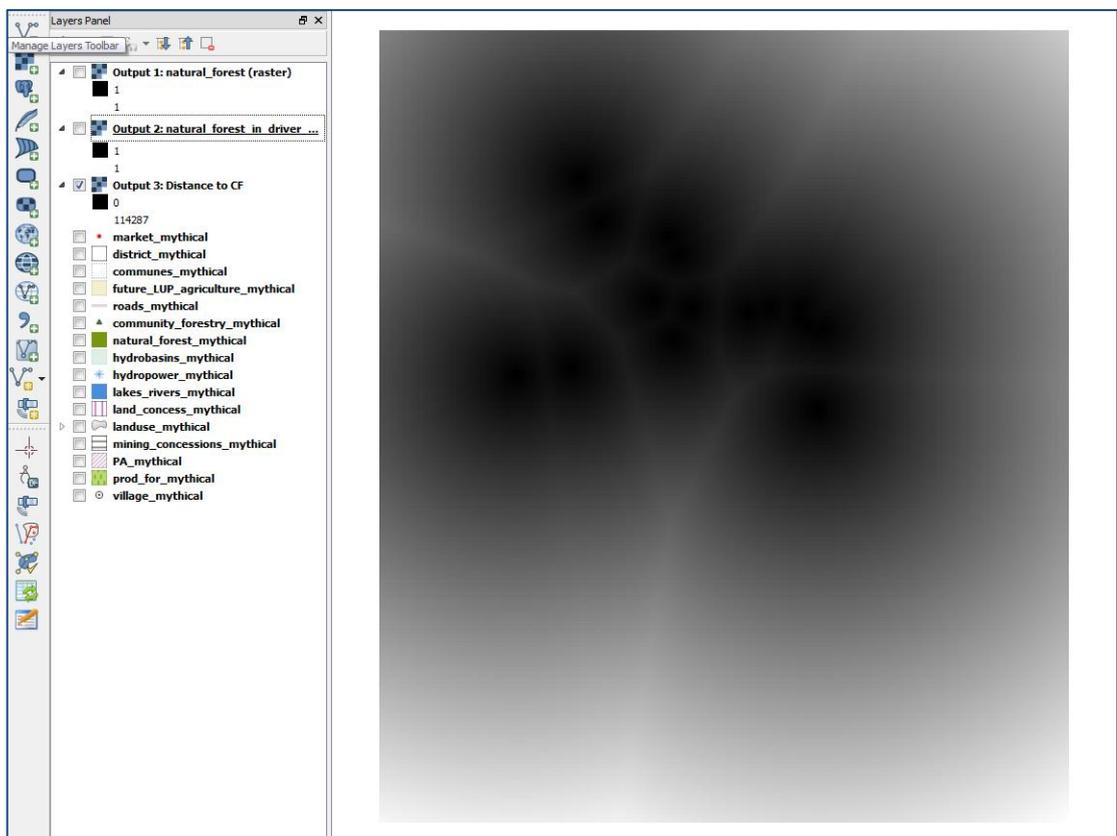
- i. Set the extent by adding the raster layer bound created in step 1.
- j. Set the **cellsize** E.g. in this example **1000**
- k. Click **OK** to add the tool
- l. Click on the **Algorithms** tab, search for **r.grow**



- m. Double click to add the **r.grow.distance** tool
- n. Change the description to as for example **Step 4: Distance from community forestry**
- o. Set the **Input raster layer** to '**Rasterized**' from algorithm '**Step 3: Convert community forestry vector to raster**'
- p. Set the extent as "**Extent**" from algorithm "**Raster layer bounds**"
- q. Set the **cellsize** E.g. in this example **1000**
- r. Give the **Distance<Output>** parameter a name e.g. **Output 4: Distance to CF**
- s. Click **OK** to add the tool



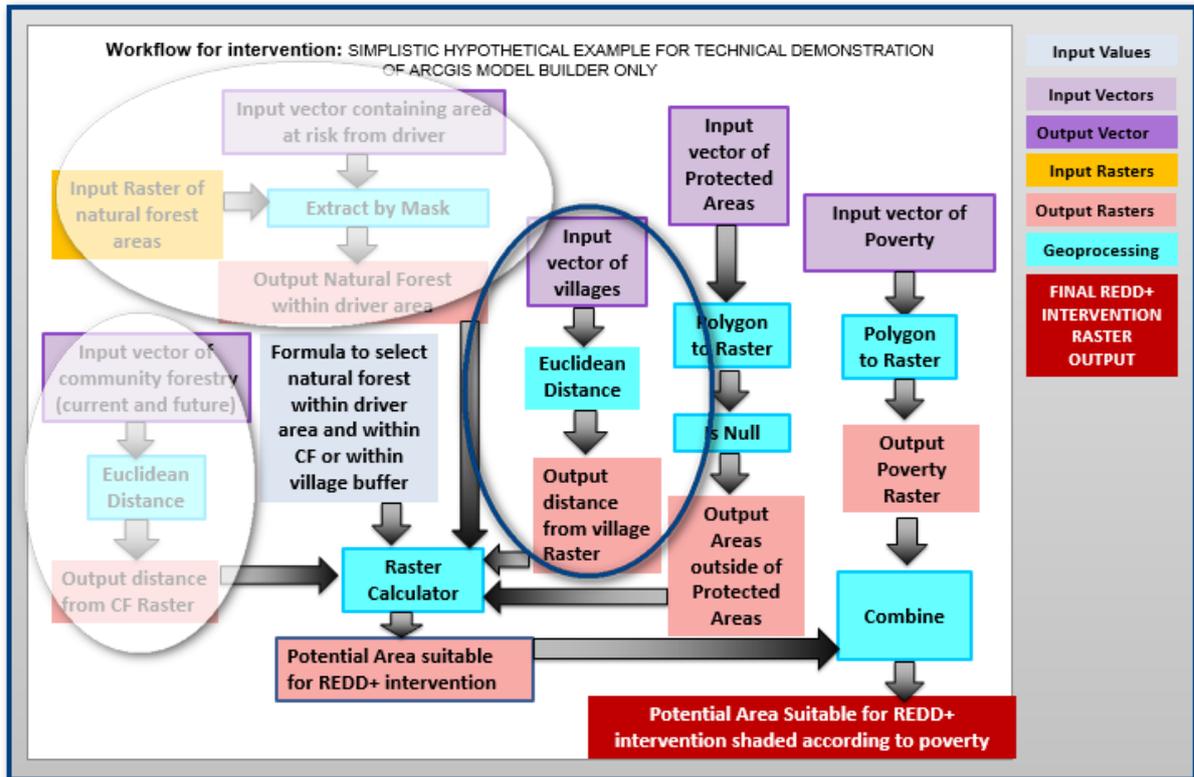
- t. Click the **Save** button to save the model
- u. Click on the **Edit model help** button to add help documentation to the new steps in the model.
- v. Expand the **input parameters**, click on **community forestry** and type the following description:
Choose a vector point layer that shows only community forestry sites. You will need to have pre-prepared this layer before running the model, this workflow does not create this layer for you.
- w. Expand the **outputs**, click on **Output 4: distance to CF** and type the following description:
Output from the tool showing a raster surface of distance to community forestry sites.
- x. Click **OK** and then click the **Save** button to save the model and model help.
- y. Click the **Run model** to test it.
- z. Once the processing is complete the outputs are added to the table of contents.



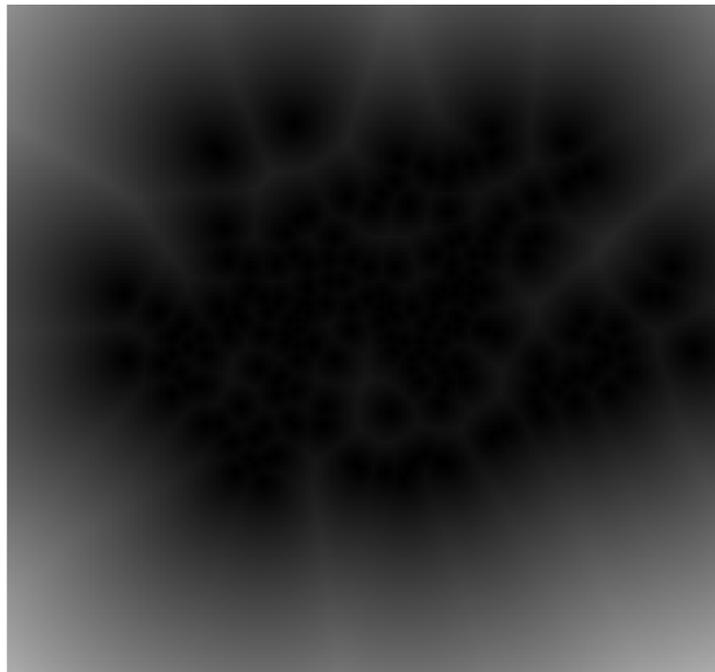
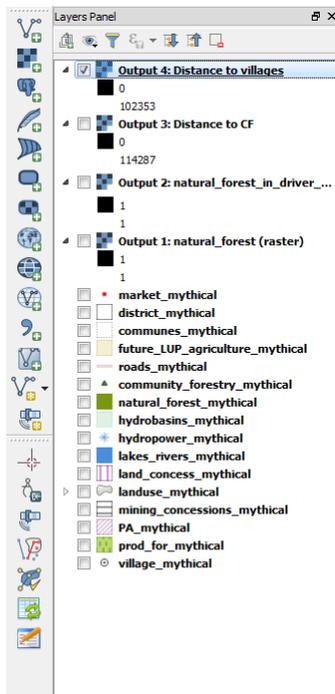
Whilst the workflow is needed to guide us through the analysis, it is common to find that the tool you planned to use is either not appropriate or the step can be done in a better or simpler way and in QGIS there are often multiple tools that can perform the same or similar function, so if one tool does not work try another.

5.4.5.2. Distance to villages

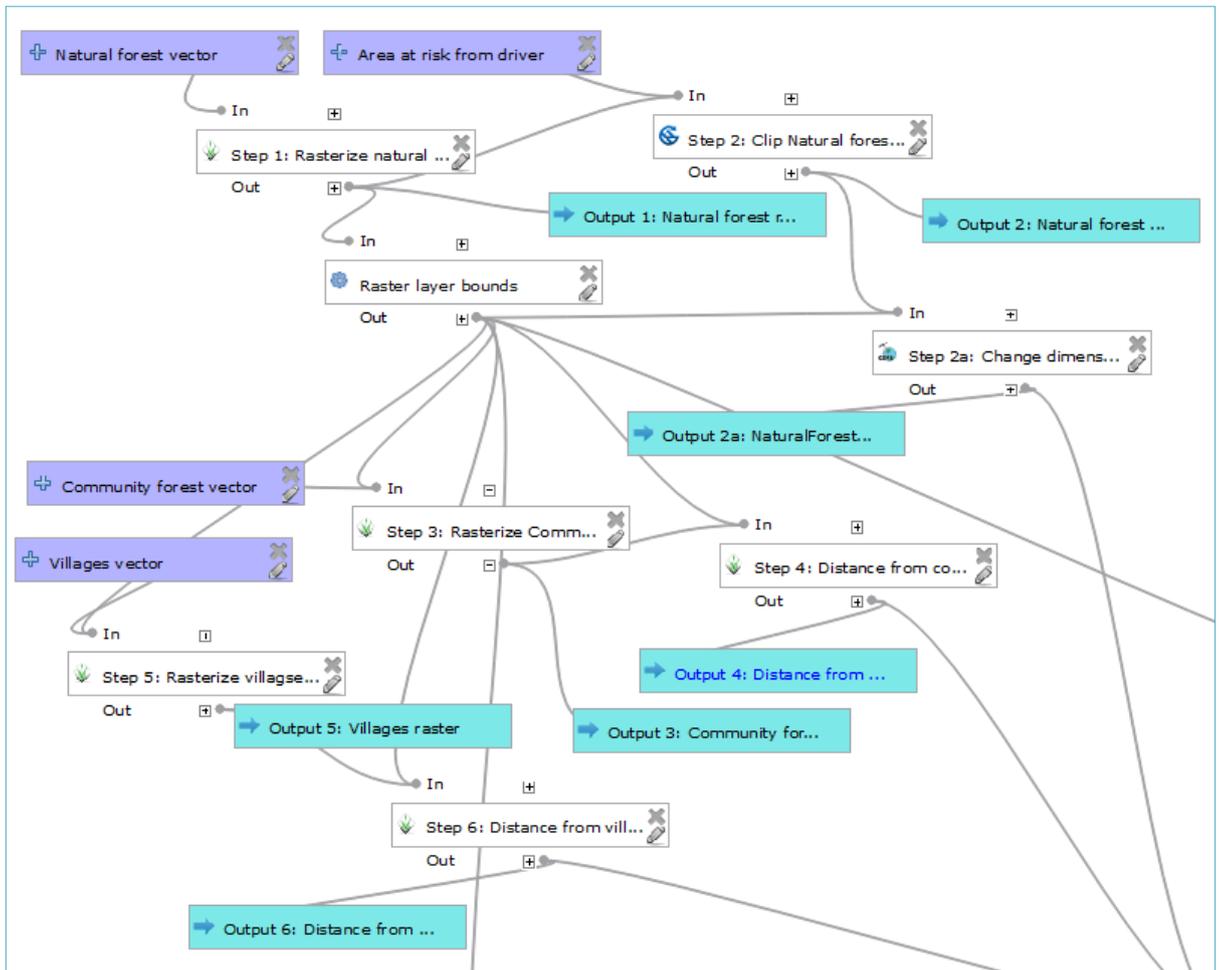
Look at your workflow design again to check what the next step is to add to Model Builder. There is another **Euclidean Distance** tool on the right. This will generate an output distance to villages raster.



Repeat the **steps a-x** from **section 5.4.5.1** but this time generating distance to villages. The output will be added to the table of contents as illustrated below.



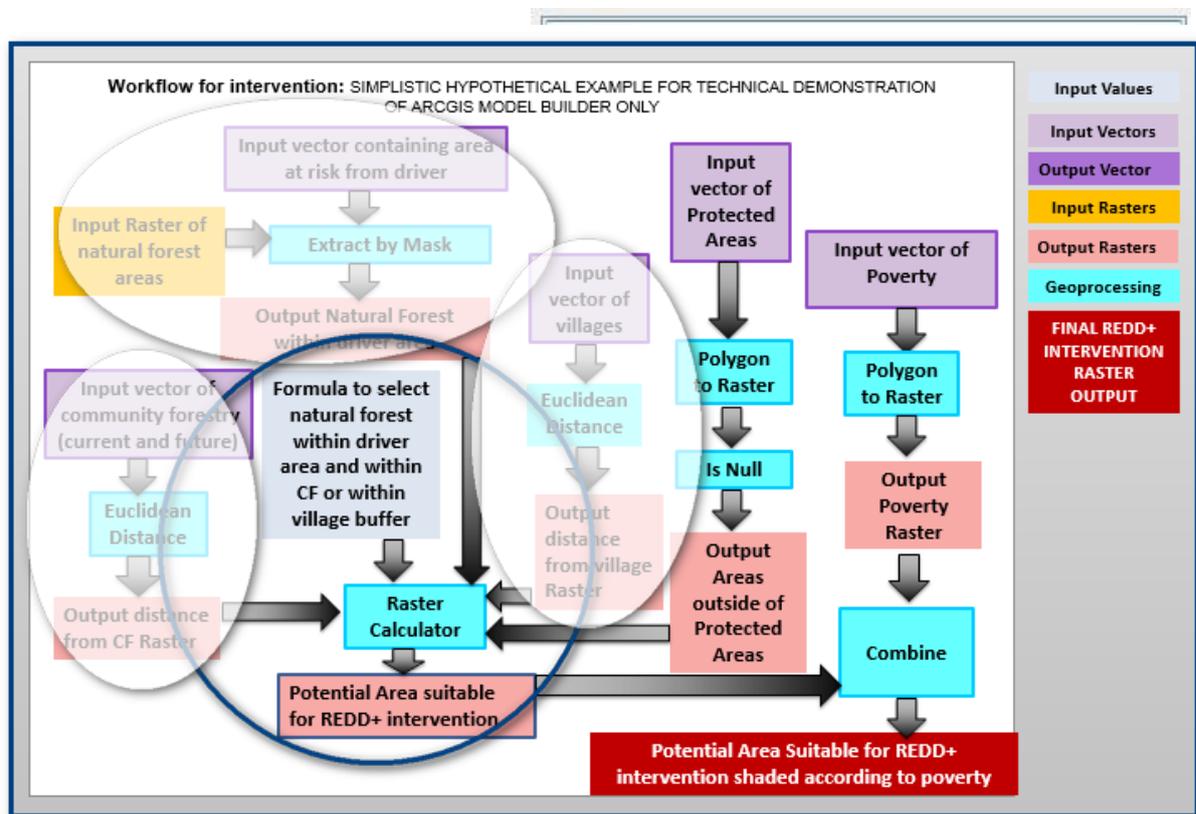
The workflow should currently look like the illustration below. Notice Steps 1 and 2 are linked, steps 3 and 4 are linked and steps 5 and 6 are linked but currently the three pairs of steps are not joined together.



It does not matter which order these three groups of steps run in but they must be run before the next step. The next step requires outputs from these three groups of steps and will therefore join the model together.

5.4.6. Select areas of natural forest within driver extent and within specified distances

Look again at your workflow design and see what the next step is to add to Model Builder. In the workflow diagram there is a **Raster Calculator process tool**, which will use all the outputs from the **Extract by Mask** and **Euclidean Distance** functions to select out natural forest areas within the driver extent within a specified distance from community forestry sites and villages.



In QGIS there are three **Raster Calculator** options available for use in the Graphical modeler: **Raster calculator (GDAL)**, **r.mapcalculator (GRASS)** and **Raster calculator (SAGA)**. A raster calculator expression is used to select out the required areas. The syntax varies slightly depending upon which calculator tool you use. (See Annex 1, section A.3.5 for help on the syntax for **Raster Calculator tools**). In our example will use the **Raster calculator (GDAL)**.

We are going to use the map calculator to select out forests within the driver extent that are either within 10km of existing and proposed community forestry sites or within 3 km of villages.

- Click on the **Algorithms** tab and search for calculator.
- Double click on **Raster calculator** to add the tool to the model canvas.
- Change the **description** to **Step 7: Select natural forest within driver extent within 10km of CF or 3km of villages**.
- For Raster layer A select the result from step 2a 'Clipped (extent) from algorithm 'Step 2a: change dimension'
- For Raster layer B select the result from step 4 'Distance' from algorithm 'Step 4: Create raster surface of distance to community forestry'
- For Raster layer C select the result from step 6 'Distance' from algorithm 'Step 6: Create raster surface of distance to villages'

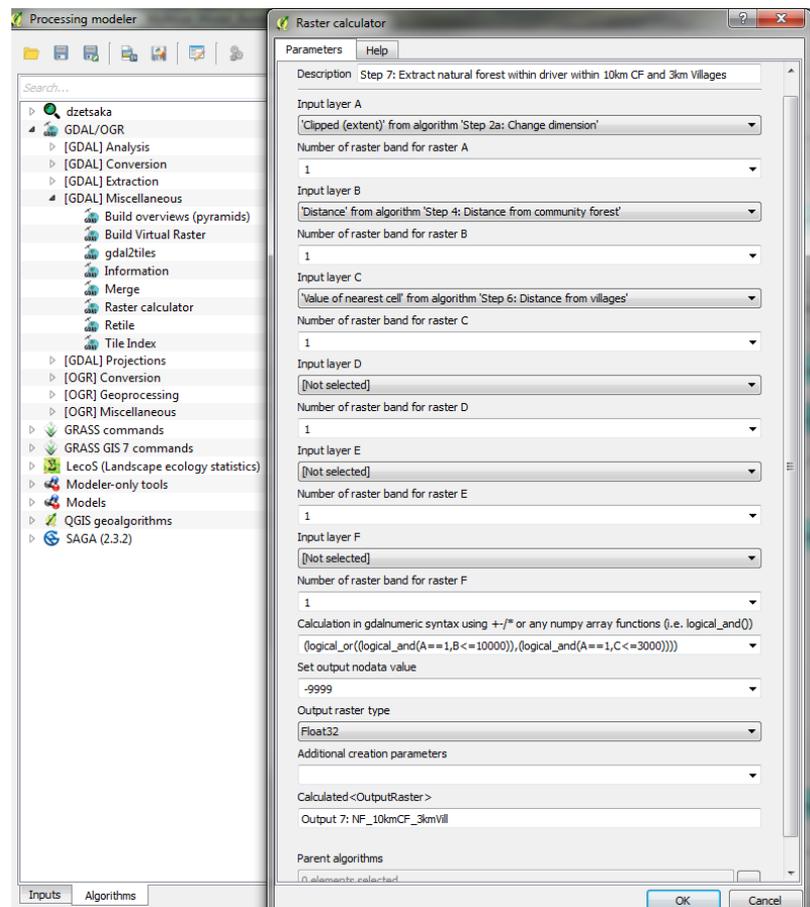
- g. In the formula box type the following expression **and be very careful in closing all the brackets**

(logical_or((logical_and(A==1,B<=10000)),(logical_and(A==1,C<=3000))))

This means **select** cells in raster A (i.e. forest within the driver extent) have a value of 1 and cells in Raster B that are less than or equal to 10km (i.e. distance to proposed and existing community forestry sites) **OR** cells in raster A (i.e. forest within the driver extent) have a value of 1 and cells in Raster C that are less than or equal to 3km (i.e. distance to villages). The output is the **forest areas within 10km of proposed and existing community forestry sites or within 3 km of villages**

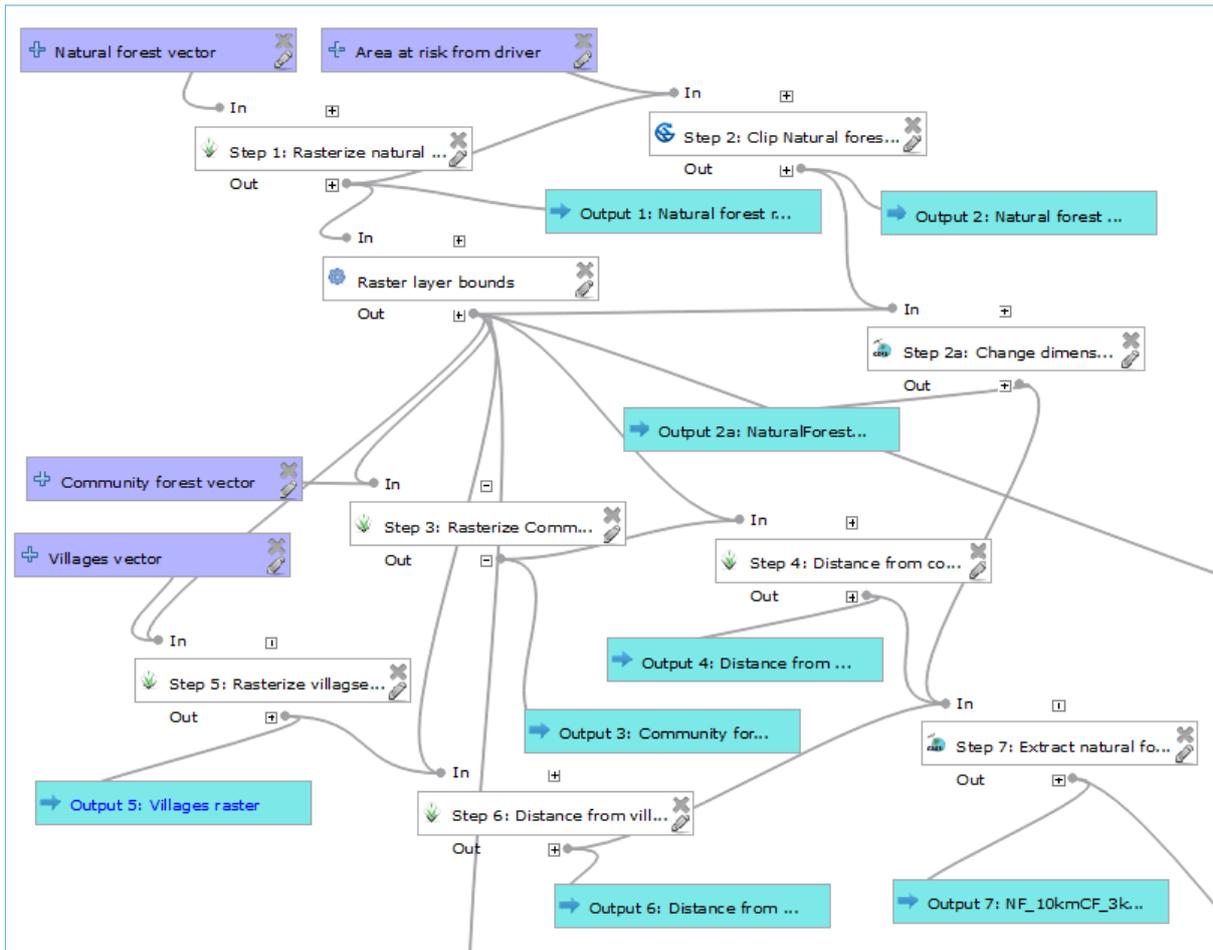
- h. Set as output no data value: -9999. This will ensure that you will have an output with the right value for the no data.

- i. For
calculated<OutputRaster>
 type **Output 6: Forest
 within driver extent and
 10km from CF or 3 km from
 villages.**



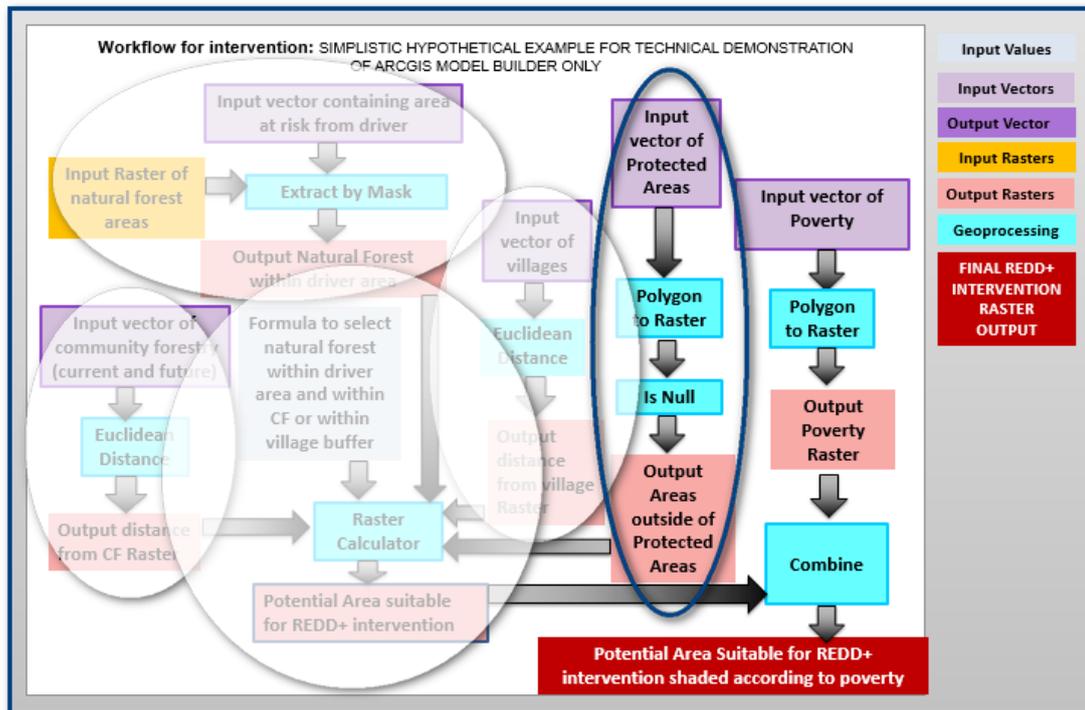
Once you have added the new step, remember to click on the **edit model help** button to add your help text for the new step. Remember to save your model.

The 3 groups of steps are now linked. The model should now look similar to the illustration below:



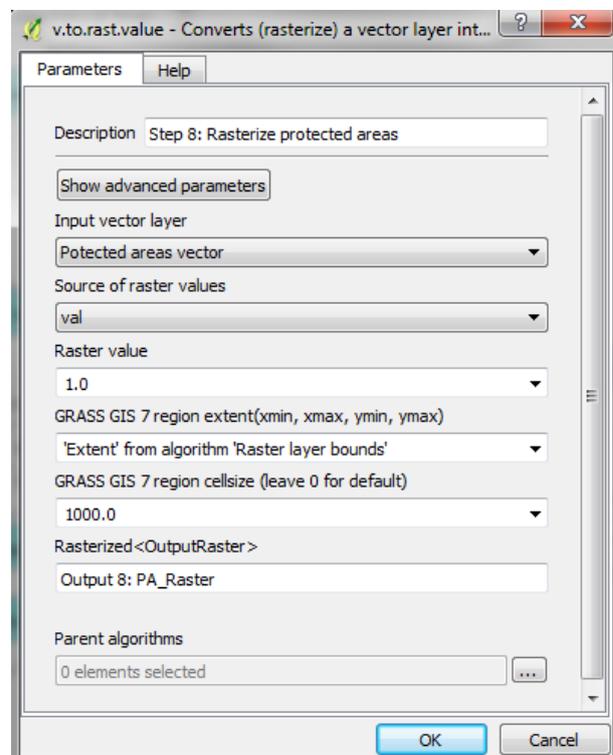
5.4.7. Exclude strictly protected areas

Check the model against the list of datasets we identified at the beginning and the workflow.



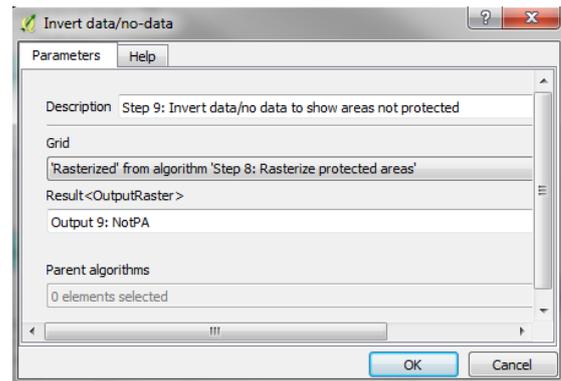
The model so far completes the first four parts of the workflow and there are two remaining. The next step to add to your model is to ‘**exclude strictly protected areas**’

- The protected areas are a vector layer so add a **Vector layer** and a **v.to.rast.value** to the **Processing modeler**.
- Change the description to **Step 8: Convert protected areas vector to raster**.
- Select the **Protected Areas** parameter for the **Input Vector** layer
- Use the extent “Extent” from algorithm “Raster layer bound”.
- Set the **cellsize** E.g. in this example **1000**
- Click **OK**



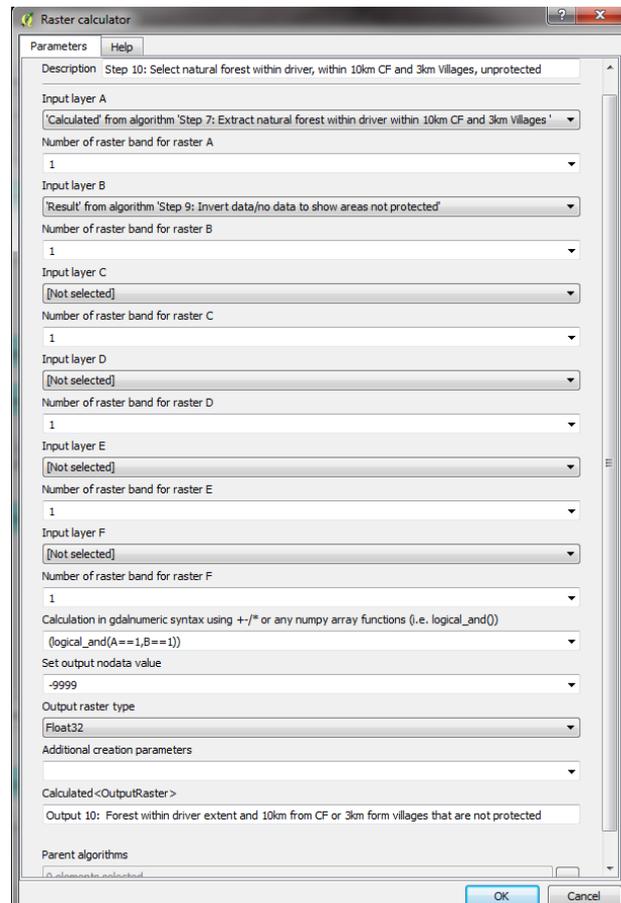
Once you have added the new step, remember to click on the **edit model help** button to add your help text for the new step. Remember to save your model.

- g. To select areas that are not under strict protection, add an **Invert data/nodata (SAGA)** tool to the **Processing modeler**
- h. Change the description to **Step 9: Invert data/no-data to show areas that are not PAs**
- i. Select the **'Rasterized'** from algorithm **'Step 8: Convert protected areas vector to raster'** for the Grid
- j. For **Result<OutputRaster>** type **Output 9: Not PA**
- k. Click **OK**



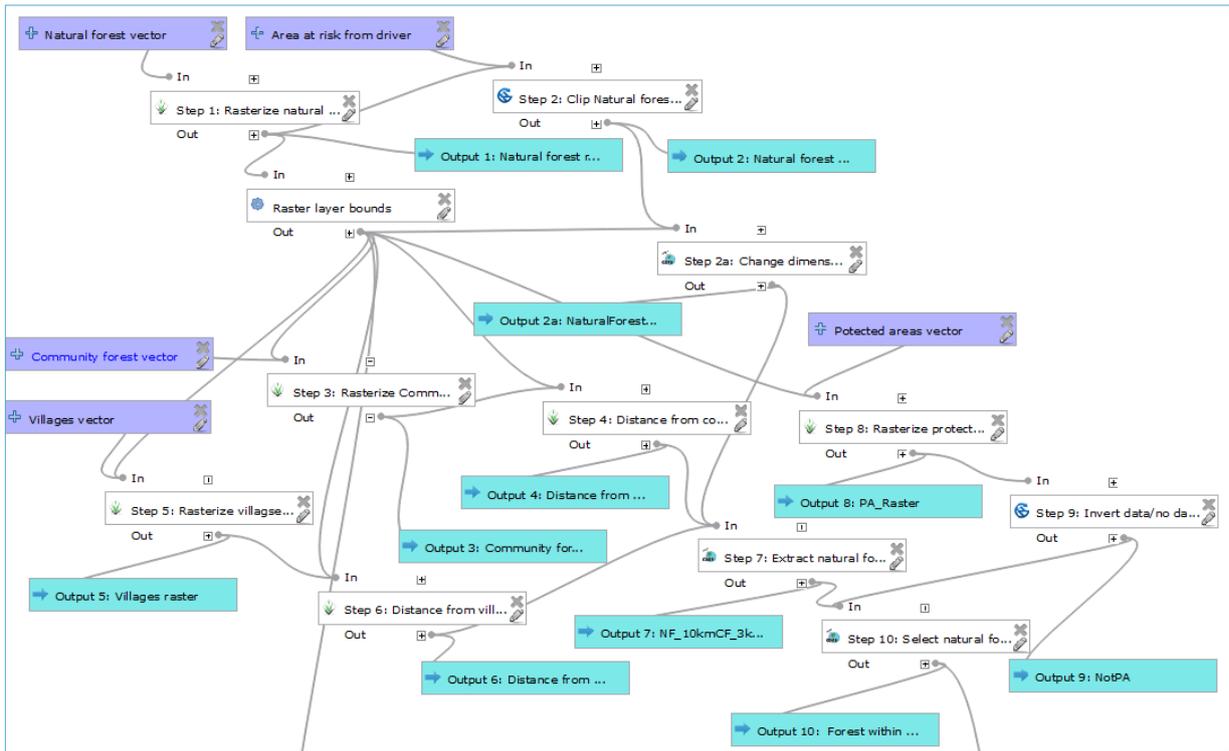
Next we use output 9 in another **Raster calculator** expression to select areas of natural forest within the driver extent that are within 10km of CF or 3km of villages

- l. Change the description to **Step 10: Select Natural forest within driver extent within 10km of CF or 3km of Villages and that are not protected**
- m. Select **'Calculated'** from algorithm **'Step7: Select natural forest within driver extent within 10km of CF or 3km of villages'** for Raster A
- n. Select **'Result'** from algorithm **'Step 9: Invert data/no-data to show areas that are not PAs'** for Raster B.
- o. In the Formula type **(logical_and(A==1,B==1))**
- p. Set the no data value as **-9999**
- q. For **Calculated<OutputRaster>** type **Output 10: Forest within driver extent and 10km from CF or 3km form villages that are not protected**
- r. Click **OK**



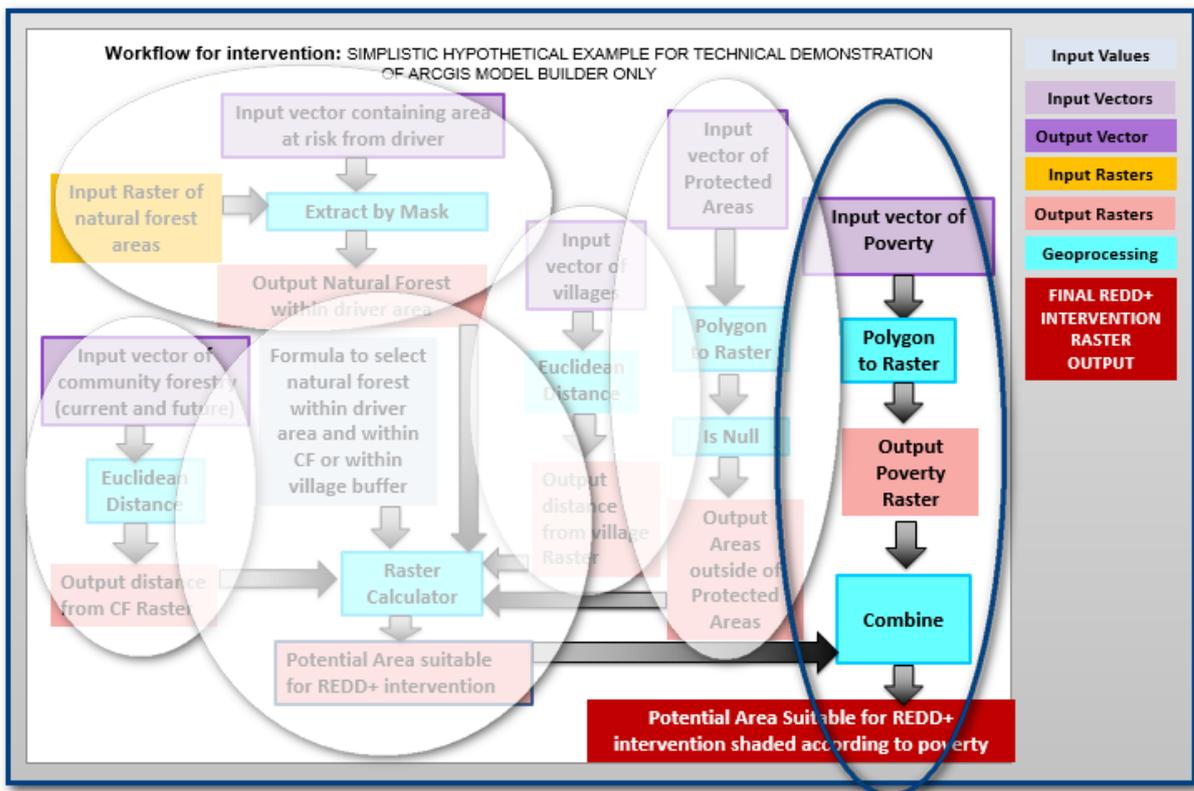
Once you have added the new step, remember to click on the **edit model help** button to add your help text for the new step. Remember to save your model.

The model should now look like this:



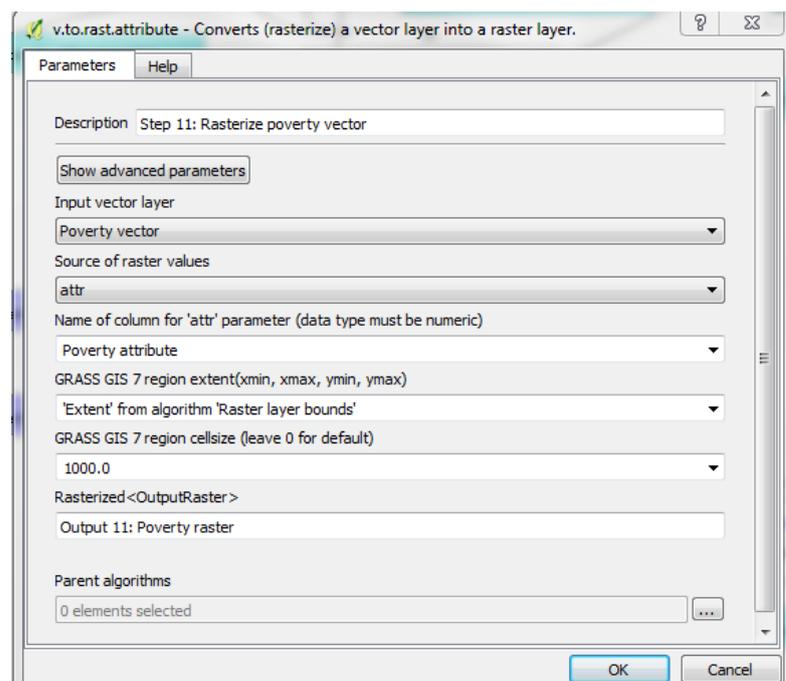
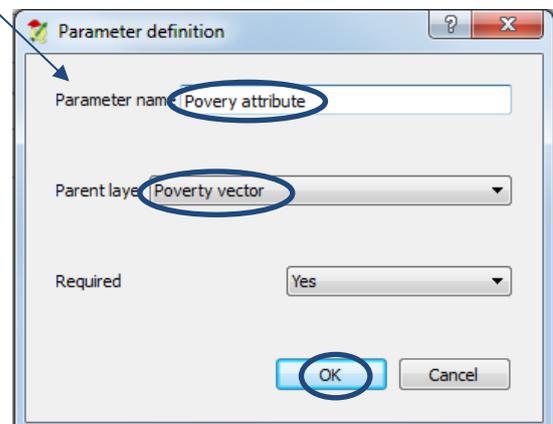
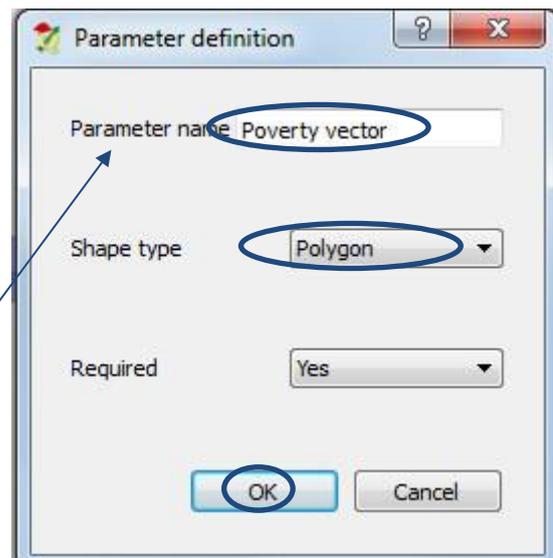
5.4.8. Identify areas to prioritize based on poverty

There is one last step in the original workflow, which is to classify the areas selected so that areas can be prioritized based on poverty. This will address one of the possible additional benefits of REDD+:

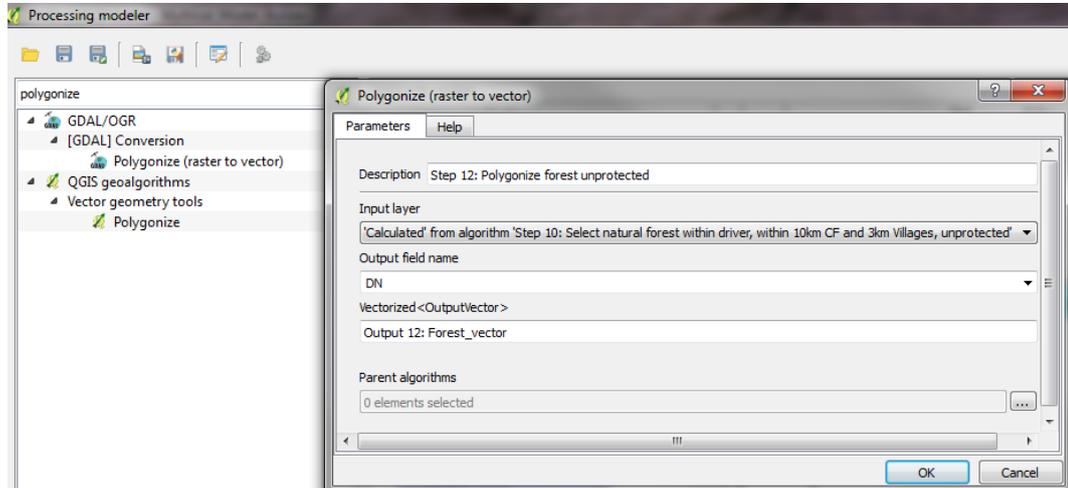


The first thing to note is that there is no raster **Combine** tool in QGIS but we can again use other technical steps to classify the layer **areas of natural forest within driver extent within 10km of CF or 3km of villages and areas that not in protected areas** according to poverty.

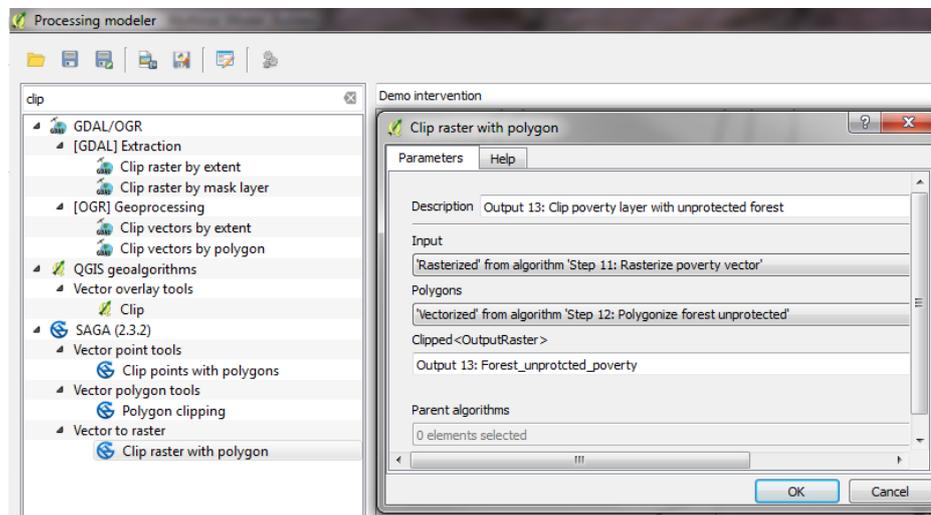
- The poverty information in our example is an attribute of the **communes_mythical** vector dataset so we need to add a new **Vector layer** called e.g. **Poverty vector** to the processing modeler.
- Next add a **Table field** called e.g. **poverty attribute** and link it to the **Parent layer Poverty vector** as this time we want to use the poverty field to make our raster dataset rather than make all the values in the raster 1
- Add a new Algorithm **v.to.rast.attribute** to the **Processing modeler**.
- Change the description to **Step 11: Rasterize poverty vector**
- Select the **Poverty vector** parameter as the **Input vector layer**
- Select the **Poverty attribute** parameter as the **Name of column for 'attr' parameter**
- Set the region extent to **'Extent' from algorithm 'Raster layer bounds'**
- Set the **cellsize** E.g. in this example **1000**
- Click **OK**



- j. Create a polygon from the output generated in Step 10: Select natural forest within driver, within 10km CF and 3km villages, unprotected, using the GDAL tool “Polygonize (raster to vector)”
- k. Give the output the name: Forest_vector

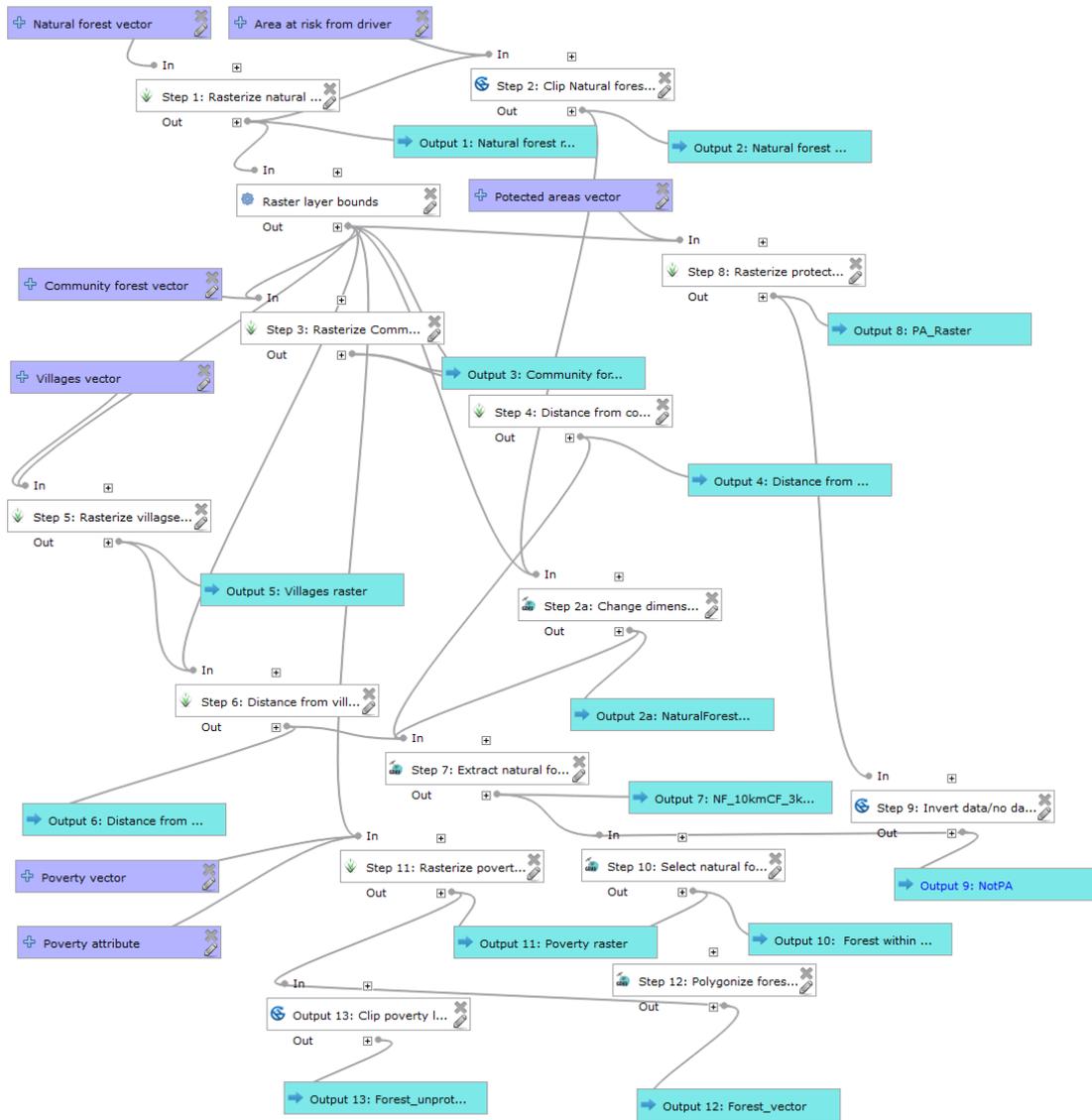


- l. Now use the SAGA tool “Clip raster with polygon” to create a raster showing unprotected forest within 10 km from community forest and 3 km from villages by poverty classes.



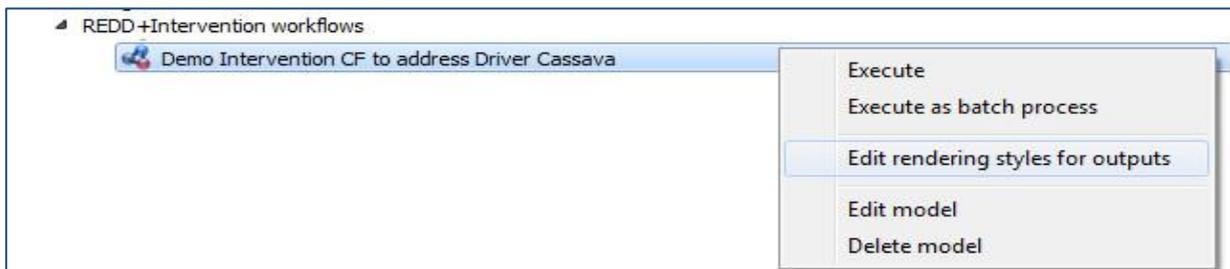
- m. Save and close the Processing modeler

The model is now complete and the user interface should look similar to this:



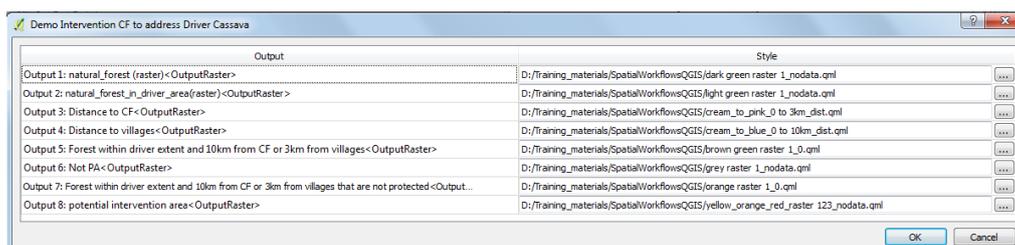
5.5. Setting symbology for the model outputs

When the output of the tool is added to the Table of Contents, the default Symbology is used. You can pre-set the Symbology for your results. In your model, right-click on the **Output Feature Class** and select **Edit rendering styles for outputs**. You can assign a pre-defined QGIS style file to determine the Symbology as long as you know what the range of output values will be i.e. you know the minimum and maximum values. For example, for processes that produce boolean outputs, you know the output values will be either 1 or 0 and therefore symbology can be created to display the 1 and 0 in a chosen colour. In some processes you will not know what the minimum and maximum values in the output file will be until the process is run and therefore a pre-defined style cannot be selected.

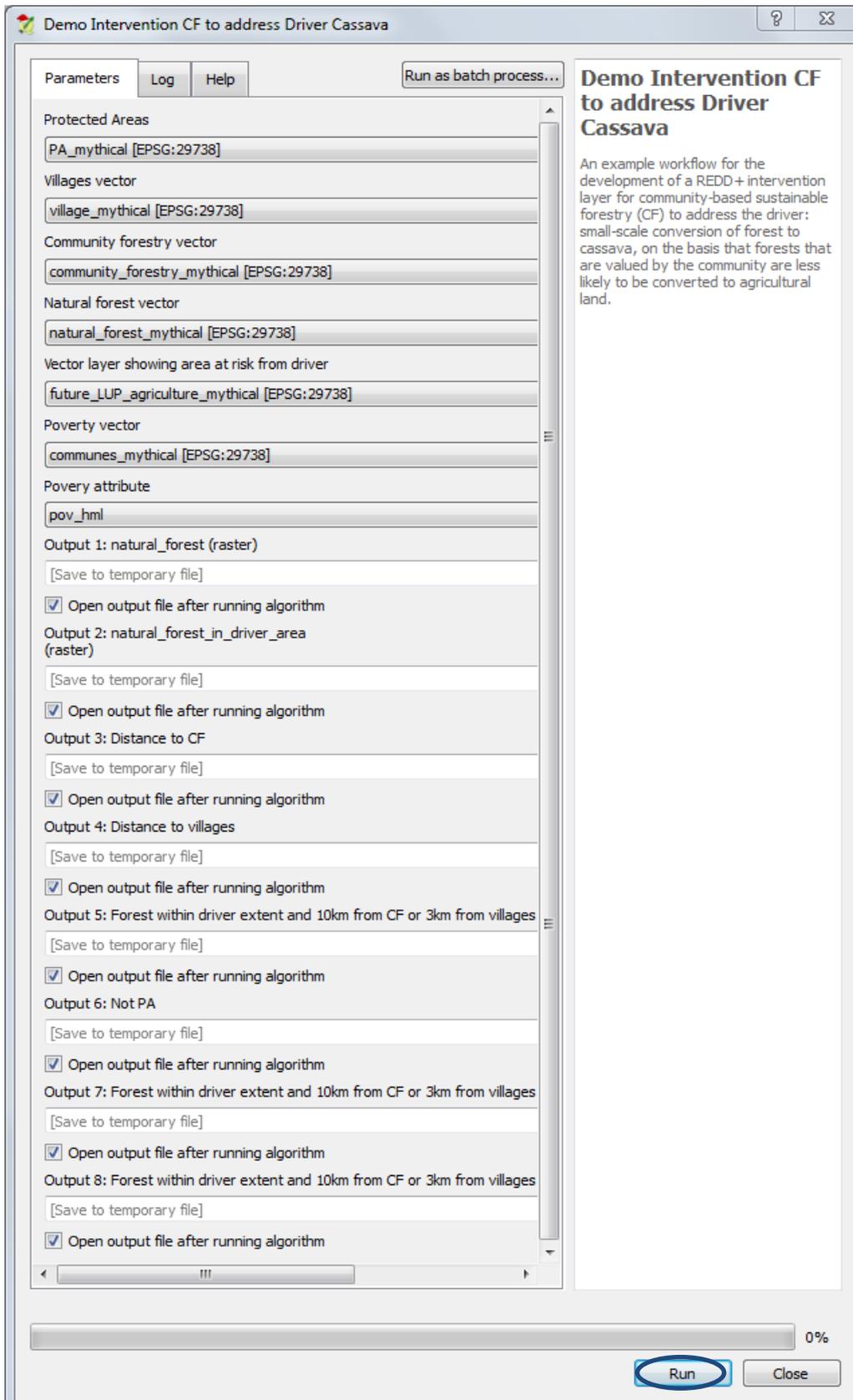


In this example pre-created style files have been created for all the outputs.

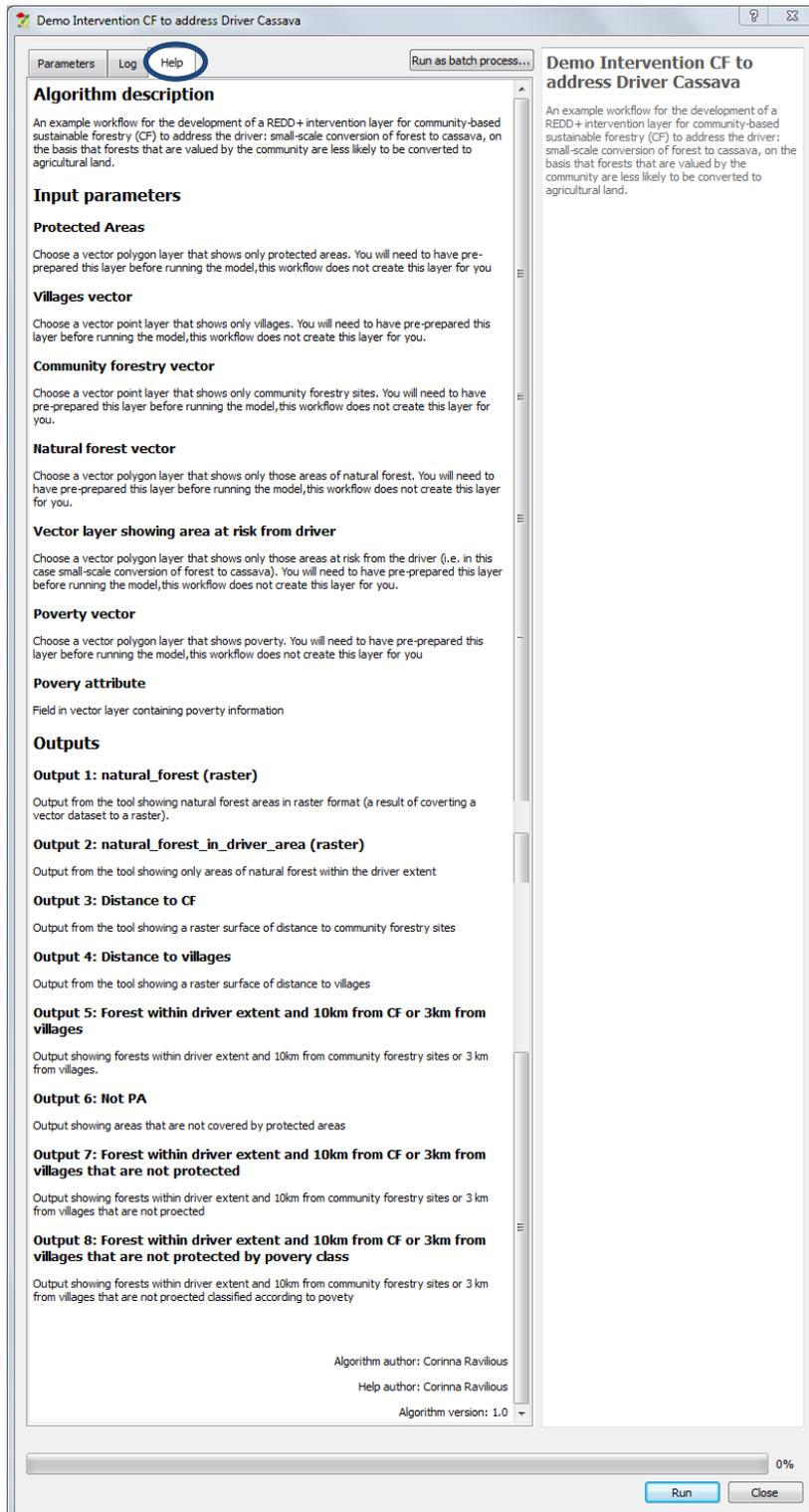
- Output 1 results in an output containing values of 1 and no data. Click on the ... to upload the style file for Output 1 **dark green raster 1_nodata.qml**
- Output 2 also results in an output containing values of 1 and no data. Click on the ... to upload the style file for Output 2 **light green raster 1_nodata.qml**
- Output 3 results in an output with a range of distance values. We are only interested to know which areas are above and below 3km so a stylefile can be uploaded as we do not need to know the maximum value in the file. Click on the ... to upload the style file for Output 3 **cream_to_pink_0 to 3km_dist.qml**
- Output 4 results in an output with a range of distance values, this time we are only interested to know which areas are above and below 10km. Click on the ... to upload the style file for Output 4 **cream_to_blue_0 to 10km_dist.qml**
- Output 5 results in an output containing values of 1 and 0. Click on the ... to upload the style file for Output 5 **brown green raster 1_0.qml**
- Output 6 results in an output containing values of 1 and no data. Click on the ... to upload the style file for Output 6 **grey raster 1_nodata.qml**
- Output 7 results in an output containing values of 1 and 0. Click on the ... to upload the style file for Output 7 **orange raster 1_0.qml**
- Output 8 results in an output containing values of 1,2,3 and nodata. Click on the ... to upload the style file for Output 8 **yellow_orange_red raster 123_nodata.qml**



5.6. Running the entire model and checking the results

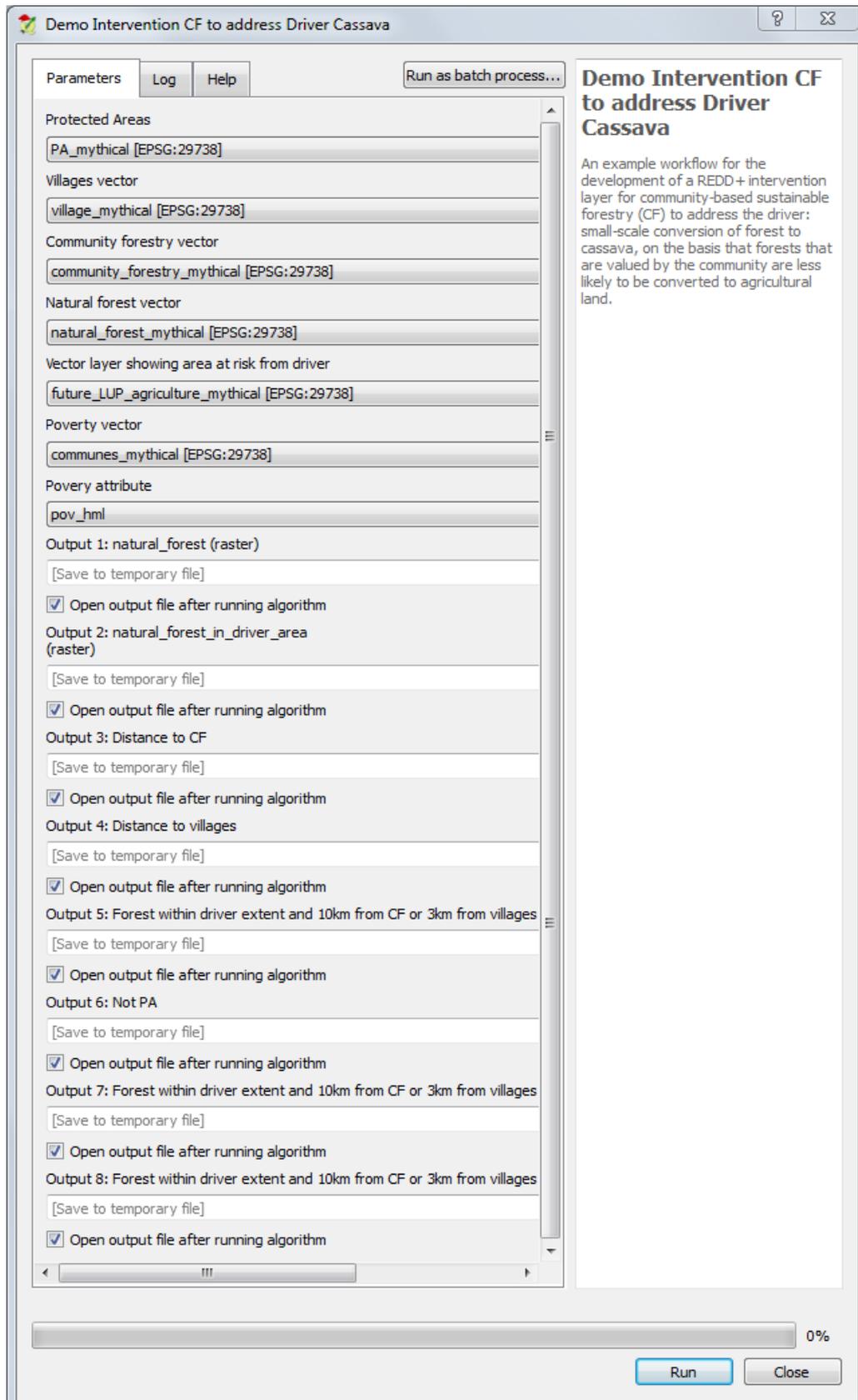


- j. Double click on the model in the **Processing toolbox** and click **Run** to run the model.
- k. Click on the **Help** to see help for each of the inputs



- I. Click on the **Parameters** tab to return to the tool dialogue.

m. Fill in the **input and output** parameters as in the illustration below.

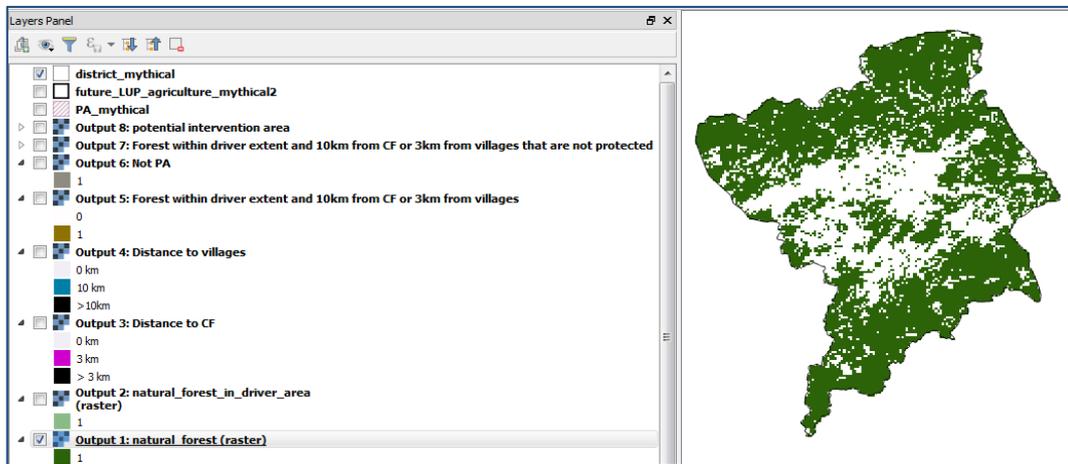


n. Click Run to **Run** the tool.

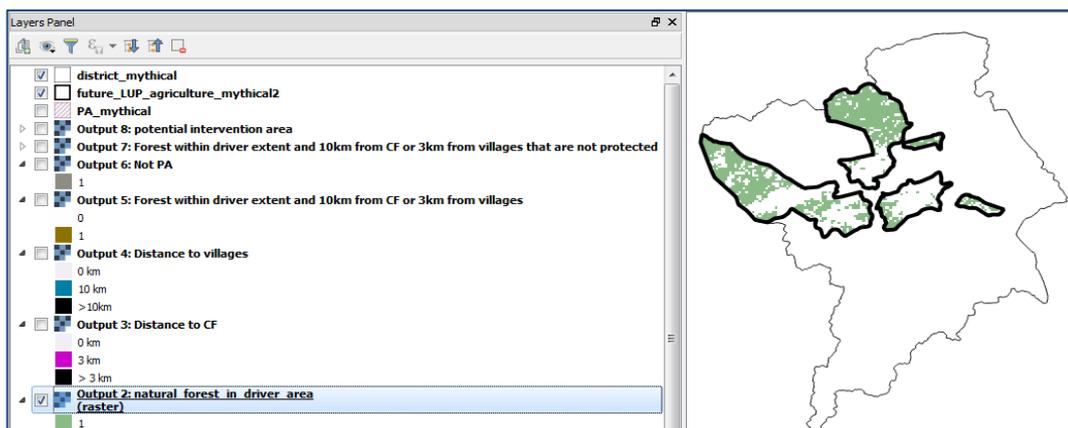
*****It is IMPORTANT to check the outputs of the Model to make sure that there were no errors in the set-up. Just because it has run, does not mean that it is giving the output you want*****

For example, in our demonstration model the outputs are below:

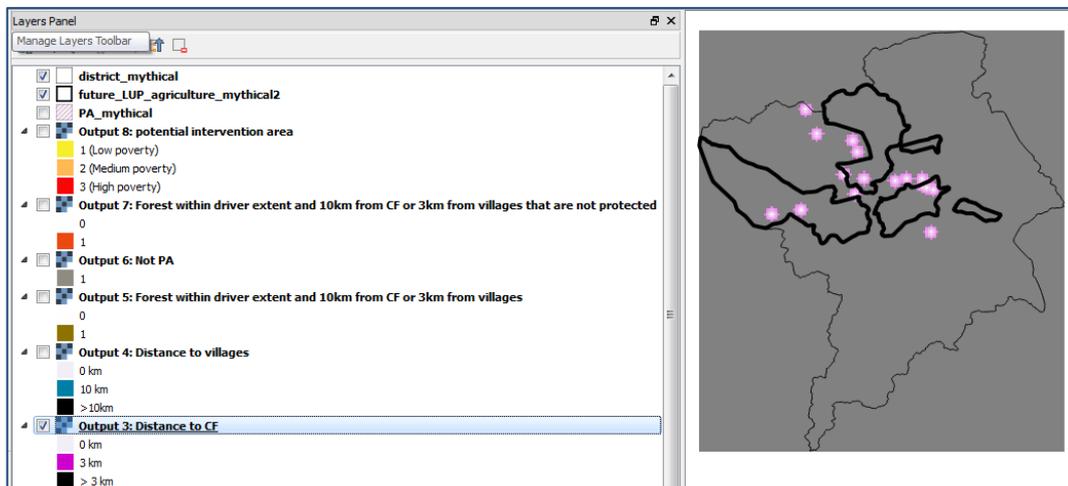
- Output 1 is a natural forest raster layer (green). We can see it correctly covers the full extent of the district and there are white areas of **No Data** where there is no natural forest.



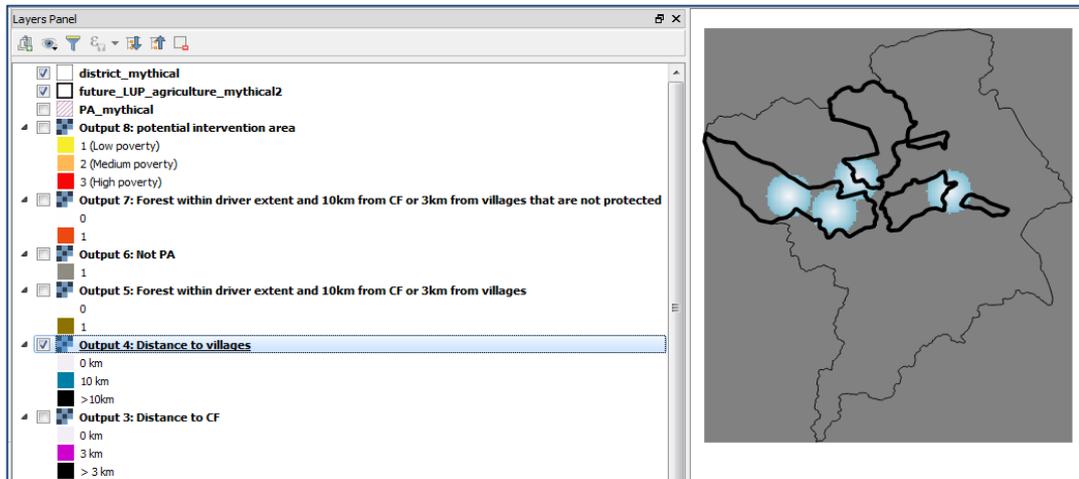
- Output 2 is the natural forest within the driver extent. We can see it correctly covers the full extent of the driver areas and there are white areas of **No Data** where there is no natural forest.



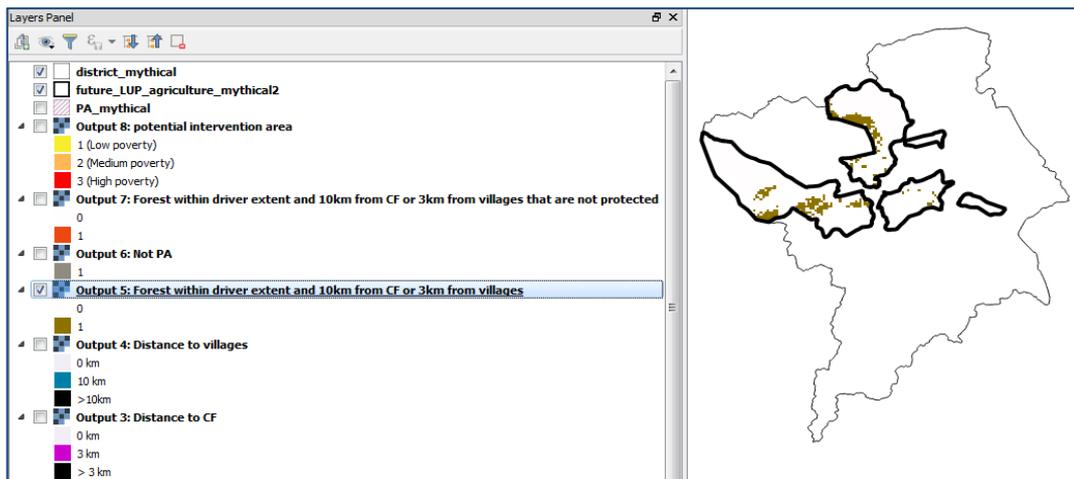
- Output 3 is the Euclidean distance from community forestry areas. We can see that it correctly covers the full extent of the district but extends beyond the district. This does not matter at this stage as long as it covers the full extent of the district. The black appears grey as a transparency has been set on the output symbology.



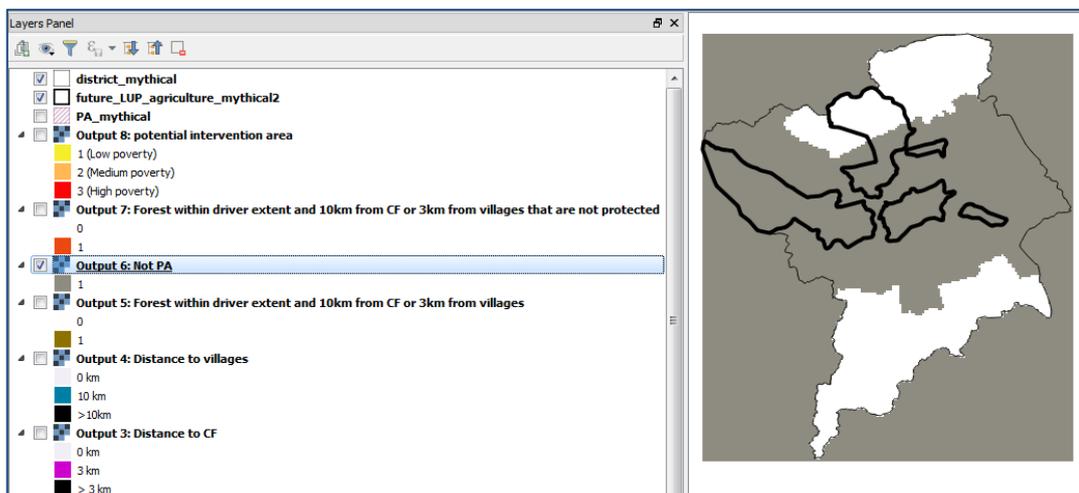
- Output 4 is the Euclidean distance from villages. Again we can see that it correctly covers the full extent of the district but extends beyond the district. This does not matter at this stage as long as it covers the full extent of the district. The black appears grey as a transparency has been set on the output symbology.



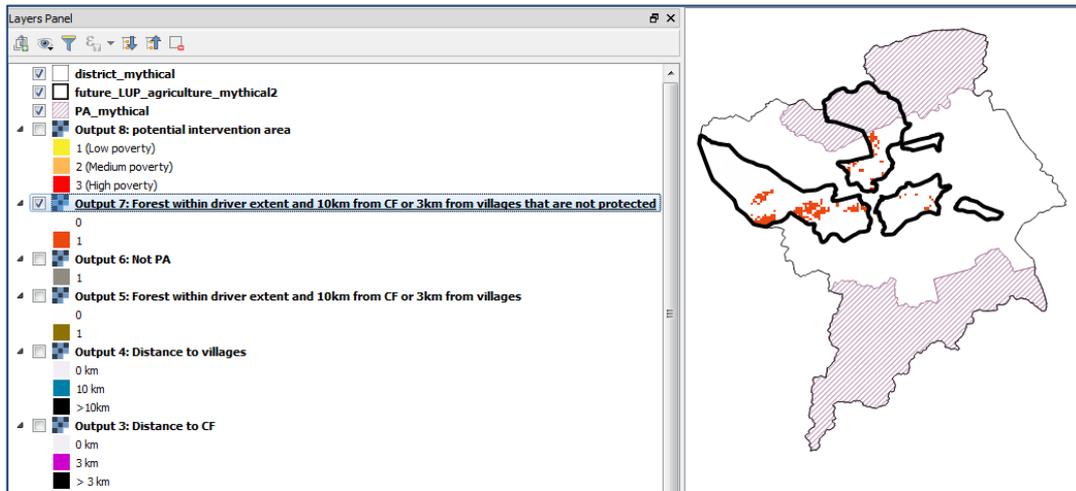
Output 5 shows the **brown areas** are the areas that have been selected as areas within natural forest, that are within 10km of existing or proposed community forestry sites or within 3km of villages. The **white areas** are the areas that have been excluded in this step.



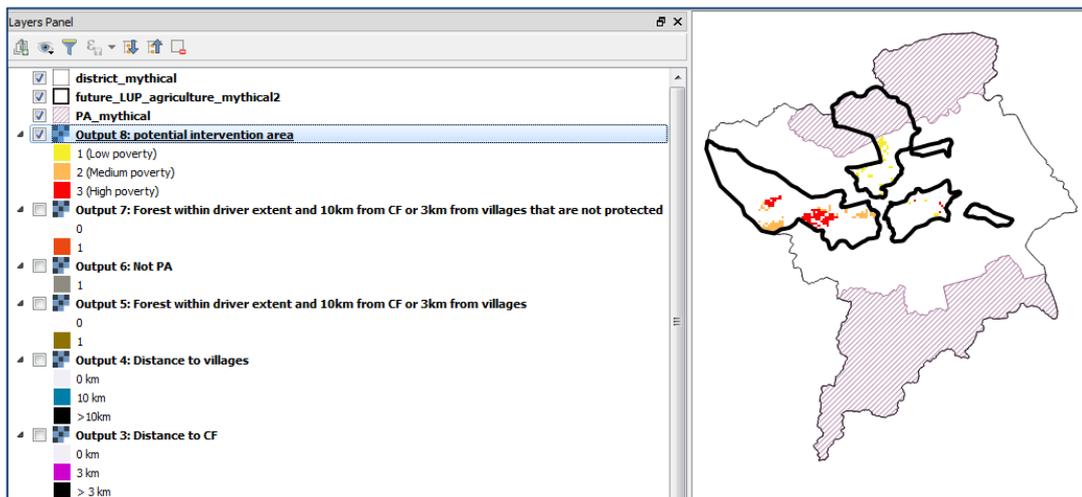
- Output 6 shows **grey areas** that are not protected and **white no data** for areas that are protected



- Output 7 shows the **orange potential intervention areas**, the areas that have been selected as areas within natural forest, that are within 10km of existing or proposed community forestry sites or within 3km of villages outside of protected areas.



- And if we look at the final layer Output 8 we can shade **these potential intervention areas by poverty class**. You will see that the poverty class has values of 1 - 3 in this example where 1 = low, 2 = medium and 3 = high.



5.7. Sharing a QGIS Model with other users

The easiest way to share a tool you have created is to **simply copy the .model file using Windows Explorer**, in the same way as you would any other file. The default location for storing models is `C:\Users\xxxxxxx\.qgis2\processing\models`.

Some custom tools break when QGIS versions change, usually because a geoprocessing tool has changed or works slightly differently to the old version. In these instances it may be necessary to select and delete that step in the Processing Modeler window and drag in a new version of the tool.

A Annex 1: Guidance notes on raster analysis and geoprocessing tools in ArcGIS and QGIS

A.1. Vector vs raster

A.1.1. Differences between vector and raster datasets

Data can be divided into two broad types: **discrete data**, which represents objects and can be stored either as **vector features** or as **raster**, and **continuous data**, which are usually (and best) stored in **raster data formats**. See Table 1 for further information on the differences between vector and raster data.

With **discrete data**, there is a clear starting point and ending point. It is easy to define the boundary of the object - a lake, for example, is a discrete object as its boundary can be definitively established. Other examples of discrete objects include administrative units (i.e. boundaries defining a region or country) or boundaries between different land-cover classes. Cells belonging to each discrete object are given the same values and are stored as Integers. **Integer** rasters cannot store decimal places. Discrete data are sometimes called categorical data.

With **continuous data**, values change smoothly across a landscape or surface and there are no discrete class breaks. Cells have individual values, with neighbouring cells often being different from each other, but having a relationship between each other. Examples of continuous data include elevation, slope and aspect, or data such as Normalized Difference Vegetation Index (NDVI) from a remotely sensed image. The numeric cell values can be either be stored as **integer** or **floating-point** rasters. **Floating-point** rasters are necessary for storing **continuous** data which have value attributes containing decimal places.

Table 1: summary of some differences between vector and raster data

Vector data	Raster data
Points, lines, polygons	Surface of regular sized grid cells or pixels
Storing discrete data e.g. data with discrete boundaries such as country boundaries, roads, streets, location of a place.	Raster cells storing either discrete data e.g. classified landcover data or continuous data e.g. elevation or satellite imagery. Raster data are especially suited to continuous data .
Complex spatial relationships can exist within and between vector layers. Topology rules can be set up (i.e. relationships between adjacent or neighbouring features) such that they do not overlap.	Spatial relationships are based on the location, size and alignment of the cells/pixels only.
Vector data have attribute tables. For each feature (in singlepart datasets) or group of features (in multipart datasets), fields can be added to store additional information about the polygon(s), point(s) and line(s)	For integer rasters, cell values may be stored in summary tables known as Value Attribute Tables (VATs). Additional information can be stored in fields for groups of cells with the same value. Attributes cannot be added to individual cells/pixels. ArcGIS can create and see VATs but in QGIS cannot. Floating point rasters never have attribute tables.
Query, select and overlay analysis is possible. Overlay of too many datasets can result in small sliver polygons where boundaries do not exactly match. This tends to slow down analyses or when severe, can cause analyses to fail when combined data become too large for processing.	As well as query, select and overlay analysis, there are many analyses better suited or only possible with raster data. Data are transformed to a consistent cell resolution to perform analyses, allowing quick and efficient analysis of multiple datasets.

A.1.2. Vector vs raster analysis

Many analyses are better suited or only possible with raster data. You can create, query, map, and analyse data with both vector and raster data. However, vector analysis only allows you to undertake some simple overlay operations compared to some of the more complex multi-criteria analyses options that are available with rasters. Raster analysis functions also allow you to do integrated raster and vector analysis, derive new information from existing data and run multi-criteria analysis queries across numerous data layers.

Table 2 provides a brief overview of some of the common vector and raster functions. This will help identify and locate raster functions that are equivalent/similar to vector functions. There may also be other functions that perform similar tasks which are not listed. **It is important to read the help for the individual tools as the table gives only a general indication of the function of the different tools listed. Individual tools may perform slightly differently.** The descriptions and tool names are mainly based on information in the ArcGIS and QGIS Processing toolboxes. In ArcGIS from the main menu click on **Help >>ArcGIS Desktop Help** or access Help Information held within the individual tools in ArcGIS toolbox. In QGIS see the QGIS user guide accessible from the main menu **Help>>Tool** or by clicking on the **Help** button on an individual tool dialogue window. Note that in QGIS help within the individual tools is not always present and you will see the message “Sorry, no help is available for this algorithm”.

In QGIS, further information can often be obtained by looking at the help pages on the internet:

GRASS <https://grass.osgeo.org/documentation/manuals/>

SAGA <http://www.saga-gis.org/en/index.html>

GDAL http://www.gdal.org/gdal_utilities.html

Table 2: Brief overview of some of the common vector and raster functions

Extraction tools	Example Vector Tools		Example Raster Tools	
	ArcGIS	QGIS	ArcGIS	QGIS
<p>Vector: Extracts input features that fall within the boundaries of the clip features. Features that fall partially within clip layer feature(s) are split along the boundary of the clip layer feature(s).</p> <p>Raster: Extracts the cells of a raster that correspond to the areas defined by a mask, polygon, within a circular radius or bounding box (extent).</p>	<p>Clip</p>	<p>Clip (QGIS)</p> <p>Clip vectors by extent (OGR)</p> <p>Clip vectors by polygon (OGR)</p> <p>Clip points with polygons (SAGA)</p> <p>Cut vector layer (SAGA)</p> <p>v.overlay (GRASS)</p> <p>v.select (GRASS)</p>	<p>Extract by Mask</p> <p>Extract by polygon</p> <p>Extract by Rectangle</p> <p>Extract by circle</p>	<p>Clip raster by extent (GDAL)</p> <p>Clip raster by mask layer (GDAL)</p> <p>Clip raster with polygon (SAGA)</p>
<p>Vector: Extracts features / table records using expressions. ArcGIS uses Structured Query Language (SQL). QGIS uses it's own expressions which are documented in the user guide https://docs.qgis.org/2.14/en/docs/user_manual/working_with_vector/expression.html</p> <p>Raster: Extracts the cells of a raster based on a logical query. Again ArcGIS and QGIS differ in their syntax. In QGIS syntax may also differ dependant upon whether a QGIS, GDAL, SAGA or GRASS.</p>	<p>Select</p> <p>Table Select</p>	<p>Select by attribute (QGIS)</p> <p>Select by attribute sum (QGIS)</p> <p>Select by expression (QGIS)</p> <p>v. extract (GRASS)</p>	<p>Extract by Attribute</p>	<p>Add raster values to points (SAGA)</p> <p>Add raster values to features (SAGA)</p> <p>Raster values to points (SAGA)</p> <p>Raster values to features (SAGA)</p>

<p>Vector: Splitting the Input Features to create subset of multiple output layers from a split layer.</p> <p>Raster: Creates a tiled output from an input raster dataset.</p>	Split	Split vector layer (QGIS)	Split Raster tool	Gdal2tiles (GDAL)
<p>Vector: Selects features in a layer based on their relationship to features in another layer</p>	Select layer by Location	Extract by location(QGIS)	N/A	N/A

Proximity tools	Example Vector Tools		Example Raster Tools	
	ArcGIS	QGIS	ArcGIS	QGIS
<p>See summary here:- http://resources.arcgis.com/EN/HELP/MAIN/10.1/index.html#//018p00000070000000</p> <p>Vector: Straight line distance tools to create buffers at specified distances</p> <p>Raster: Various distance tools that do more than straight line distance e.g. to take into account of elevation etc.</p>	<p>Buffer</p> <p>Multiple Ring Buffer</p>	<p>Fixed distance buffer (QGIS)</p> <p>Fixed distance buffer (SAGA)</p> <p>Variable distance buffer (QGIS)</p> <p>Variable distance buffer (SAGA)</p> <p>v.buffer.distance (GRASS)</p> <p>v.distance (GRASS)</p> <p>v.distance.toattr (GRASS)</p>	<p>Euclidean Distance</p> <p>Cost distance</p> <p>Path distance</p>	<p>Proximity (raster distance) (GDAL)</p> <p>r.grow.distance (GRASS)</p> <p>r.grow (GRASS)</p> <p>r.cost (GRASS)</p> <p>r.cost.full (GRASS)</p> <p>r.cost.full.raster (GRASS)</p> <p>r.spreadpath (GRASS)</p> <p>Least cost paths (SAGA)</p> <p>Accumulated cost (anisotropic) (SAGA)</p> <p>Accumulated cost (isotropic) (SAGA)</p>

Proximity tools	Example Vector Tools		Example Raster Tools	
	ArcGIS	QGIS	ArcGIS	QGIS
<p>Vector: Each Thiessen polygon contains only a single point input feature. Any location within a Thiessen polygon is closer to its associated point than to any other point input feature.</p> <p>Raster: divides an area up and allocates each cell to the nearest input feature that has a value.</p>	<p>Create Thiessen polygons</p>	<p>Voronoi polygons (QGIS) v.voronoi (GRASS)</p>	<p>Euclidean allocation</p>	<p>r.grow.distance (GRASS)</p>

Statistics tools	Example Vector Tools		Example Raster Tools	
	ArcGIS	QGIS	ArcGIS	QGIS
<p>Vector: Creates a table with statistics based on polygon contiguity (overlaps, coincident edges, or nodes).</p> <p>Raster: Calculates for each input cell location, a statistic of the values within a specified neighbourhood around it.</p>	<p>Polygon Neighbours</p>	<p>NNjoin (QGIS plugin)</p>	<p>Neighbourhood toolbox: Focal Statistics tool</p>	<p>Raster layer statistics (QGIS)</p>
<p>Reads a table and a set of fields and creates a new table containing unique field values and the number of occurrences of each unique field value.</p>	<p>Frequency</p>	<p>Frequency Analysis (QGIS)</p>	<p>For Integer rasters the value attribute table is similar to a frequency table in that it contains the unique field values and the count of the number of cells</p>	<p>Unique values count (SCRIPT) Extract raster values to CSV (SCRIPT)</p>

Statistics tools	Example Vector Tools		Example Raster Tools	
	ArcGIS	QGIS	ArcGIS	QGIS
Calculates summary statistics for field(s) in a table	Summary Statistics	Basic Statistics for numeric fields (QGIS) Basic statistics for text fields (QGIS) Statistics by Categories (QGIS)	N/A	N/A
Calculates statistics on values of a raster within the zones of another dataset. Summarizes the values of a raster within the zones of another dataset and reports the results to a table	N/A	N/A	Zonal statistics tool, Zonal statistics as table tool	r.stats (GRASS) r.univar (GRASS) r.statistics (GRASS) Zonal raster statistics (SAGA) Zonal Statistics (QGIS) Raster statistics for polygons (SAGA)
Calculates cross-tabulated areas between two datasets and outputs a table.	N/A	N/A	Tabulate Areas	Cross-Classification and Tabulation (SAGA)
Calculates a per-cell statistic from multiple rasters. The available statistics are Majority, Maximum, Mean, Median, Minimum, Minority, Range, Standard Deviation, Sum, and Variety.	N/A	N/A	Cell statistics	Statistics for rasters (SAGA) r.report (GRASS)

Overlay tools	Example Vector Tools		Example Raster Tools	
	ArcGIS	QGIS	ArcGIS	QGIS
<p>Vector: Union tool - All features and their attributes will be written to the output layer. Identity tool - The input features or portions thereof that overlap identity features will get the attributes of those identity features. Intersect tool - Features or portions of features which overlap in all layers and/or feature classes will be written to the output layer.</p> <p>Raster: Combines multiple rasters so that a unique output value is assigned to each unique combination of input values.</p> <p>Note: Also see Multicriteria analysis tools which are listed separately in this table under the Raster only tools.</p>	<p>Union</p> <p>Identity</p> <p>Intersect</p>	<p>Union (QGIS)</p> <p>Polygon identity (SAGA)</p> <p>Intersect (SAGA)</p> <p>Intersection (QGIS)</p> <p>v.overlay (GRASS)</p> <p>v.patch (GRASS)</p>	<p>Combine</p> <p>(Note: any cells in the input rasters that have No Data will be excluded from the output raster even if those cells contain data in some of the input rasters)</p>	<p>r.cross (GRASS)</p> <p>Cross-classification and tabulation (SAGA)</p>
<p>Vector: Computes a geometric intersection of the Input Features and Update Features. Attributes and geometry are updated by the update features in the output layer.</p> <p>Raster: Mosaics multiple raster datasets into a new raster dataset.</p>	<p>Update</p>	<p>Polygon update (QGIS)</p>	<p>Mosaic to New Raster</p>	<p>Mosaic raster layers (SAGA)</p> <p>r.patch (GRASS)</p>

Raster only tools	Example Raster Tools	
	ArcGIS	QGIS
<p>Multicriteria Analysis tools: Overlay analysis tools allow you to apply weights to several inputs and combine them into a single output. The most common application is for suitability modelling.</p>	<p>Fuzzy Membership Transforms the input raster into a 0 to 1 scale, indicating the strength of a membership in a set, based on a specified fuzzification algorithm.</p> <p>Fuzzy Overlay Combine fuzzy membership rasters data together, based on selected overlay type.</p> <p>Weighted Overlay Overlays several rasters using a common measurement scale and weights each according to its importance.</p> <p>Weighted Sum Overlays several rasters, multiplying each by their given weight and summing them together.</p> <p>For more detail see the Help pages:- http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/An overview of the Overlay tools/009z000000rm000000/ and this article on Fuzzy logic: http://www.esri.com/news/arcuser/0410/fuzzylogic.html</p>	<p>Fuzzify (SAGA) Translates grid values into fuzzy set membership as preparation for fuzzy logic analysis.</p> <p>Fuzzy union (or) (SAGA) Calculates the union (max operator) for each grid cell of the selected grids.</p> <p>Fuzzy Intersection (and) Calculates the intersection (min operator) for each grid cell of the selected grids.</p> <p>Ordered weighted averaging (SAGA) Overlays several rasters using a common measurement scale and weights each according to its importance.</p> <p>See the help for the Grid Calculus tools in SAGA: http://www.saga-gis.org/saga_tool_doc/3.0.0/grid_calculus.html and the grid analysis tools: http://www.saga-gis.org/saga_tool_doc/3.0.0/grid_analysis.html</p>
<p>Conditional evaluation: Performs a conditional if/else evaluation on each of the input cells of an input raster. For example if a value is > x then do this or if it isn't, do something else</p>	<p>Con tool (function can also be performed in the raster calculator)</p>	<p>Function can only be performed in the raster calculator See http://gis.stackexchange.com/questions/69734/what-is-the-equivalent-of-arcpy-con-in-qgis-and-or-r-raster-package</p>

Raster only tools	Example Raster Tools	
	ArcGIS	QGIS
<p>Set Null tool sets identified cell locations to No Data based on a specified criteria. It returns No Data if a conditional evaluation is true, and returns the value specified by another raster if it is false.</p>	<p>Set Null (function can also be performed in the raster calculator)</p>	<p>Function can only be performed in the raster calculator</p>
<p>Math tools that perform mathematical operations on rasters.</p> <p>For Multicriteria analysis Logical Math tools are useful. These evaluate the values of the inputs and determine the output values based on Boolean logic.</p>	<p>The Math toolset in ArcGIS contains tools that perform mathematical operations on rasters.</p> <p>Logical Math toolset contains tools for performing logical evaluations on rasters which look at whether statements are true or false. The tools are in the following categories: Boolean, Combinatorial, Relational, and Conditional.</p> <ul style="list-style-type: none"> ➤ The Boolean tools evaluate the inputs only as True or False conditions and return the result of the particular tool as a 1 or 0 (True or False) Boolean value. ➤ The Combinatorial tools identify unique combinations of input values based on the logic of the particular tool and return a different value for each unique combination. ➤ The Relational tools compare the values of one input relative to another and return the result of the particular tool as 1 or 0 Boolean value. <p>(functions can also be performed in the raster calculator)</p>	<p>The Raster Calculus toolset (SAGA) in QGIS contains tools that perform mathematical operations on rasters.</p> <p>No Logical math tools in QGIS. Functions can only be performed in the raster calculator.</p>

Raster only tools	Example Raster Tools	
	ArcGIS	QGIS
<p>Raster Calculator Allows you to perform custom calculations based on values within raster datasets.</p>	<p>Raster calculator Builds and executes a single map algebra expression using python syntax in a calculator type interface</p>	<p>Syntax varies depending on which calculator you use:-</p> <p>Raster calculator (QGIS) https://docs.qgis.org/2.2/en/docs/user_manual/working_with_raster/raster_calculator.html</p> <p>r.mapcalculator (GRASS) https://grass.osgeo.org/grass73/manuals/r.mapcalc.html</p> <p>Raster calculator (SAGA) http://www.saga-gis.org/saga_tool_doc/3.0.0/grid_calculus_1.html</p>

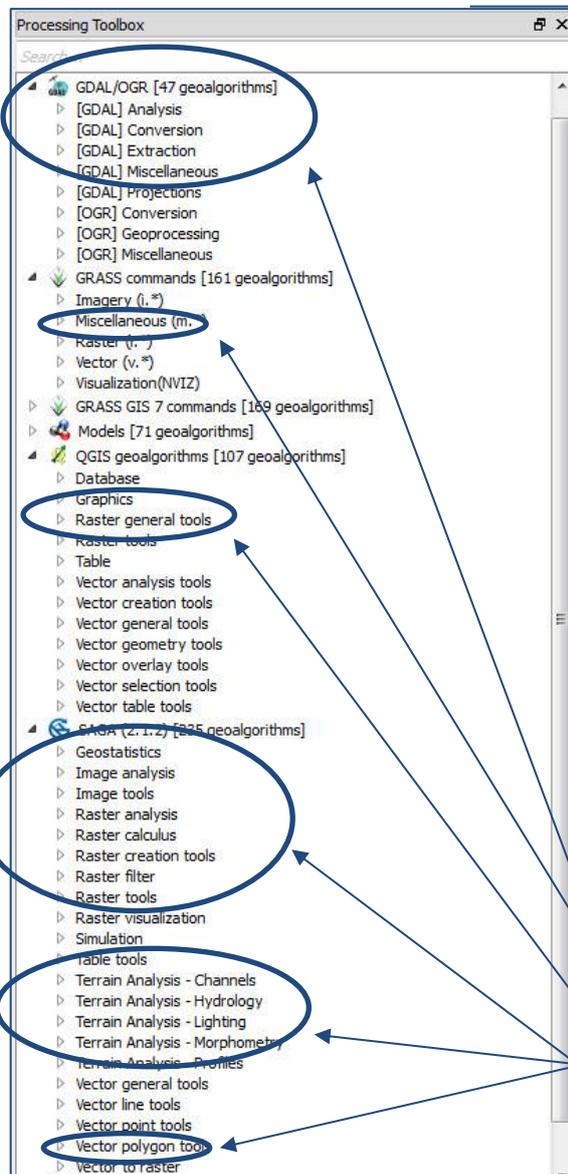
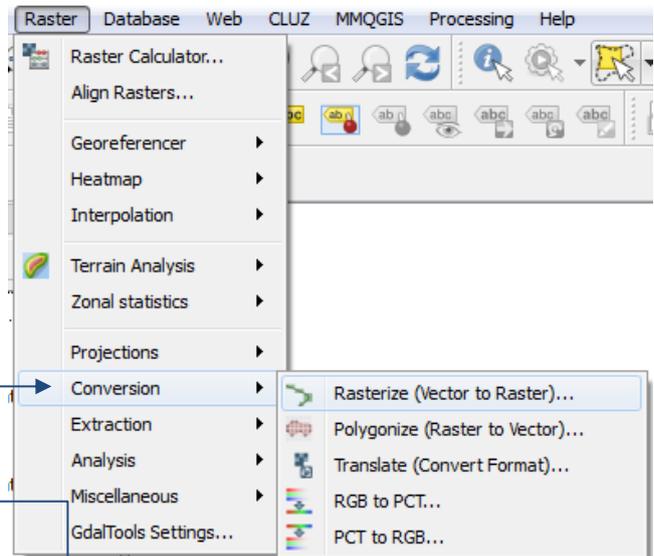
A.2. Raster analysis in QGIS

The **Processing toolbox** provides QGIS users with access to a wealth of **raster analysis tools** within QGIS, GDAL, SAGA, GRASS and more. A few raster tools can also be accessed from the **Raster** tab on the main menu.

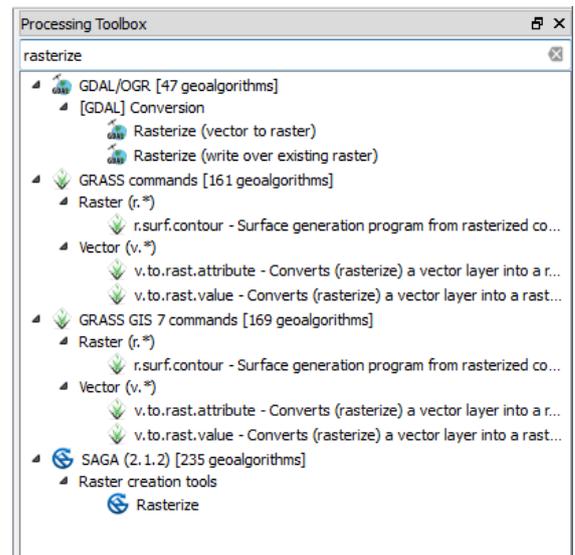
To convert from vector to raster, from the main menu under **Raster>>Conversion**

Note: There are various tools in QGIS which are very similar. Different tools can have different options. It is important to read the help and, once you have run the tool, always check the results to check it has produced an appropriate output for your task.

Various raster conversion tools are located by



searching in the **Processing Toolbox**:



Raster analysis tools are grouped together in a tool subset under each provider:

GDAL – all the GDAL tools are raster

GRASS – most are under **Raster (r.*)** although the conversion tools under Vector e.g. v.to.raster

QGIS – raster tools listed under 2 raster sub-groups

SAGA – raster tools listed under various raster sub-groups.

Some of the advantages of Raster analysis include the ability to:

- Integrate raster and vector analysis
- Derive new information from existing data
- Query information across multiple layers
- Undertake complex analyses in a more timely manner

A.2.1. Raster analysis and the environment settings

You may be familiar with setting **Environment Settings** for Geoprocessing in ArcMap. The settings are additional parameters that can be implemented to affect a tool's results. There are less hidden environment setting in QGIS but there are often settings on the individual tools that are often optional

In raster analysis this is very important, to make sure that cells are not misaligned (causing data to shift) in output layers.

In the **GRASS** tools there are settings that help to avoid such shifts

- **Grass region extent (xmin xmax ymin ymax) that can be set consistently throughout an analysis.**
- **Grass region cellsize**

and similarly in **SAGA** tools:

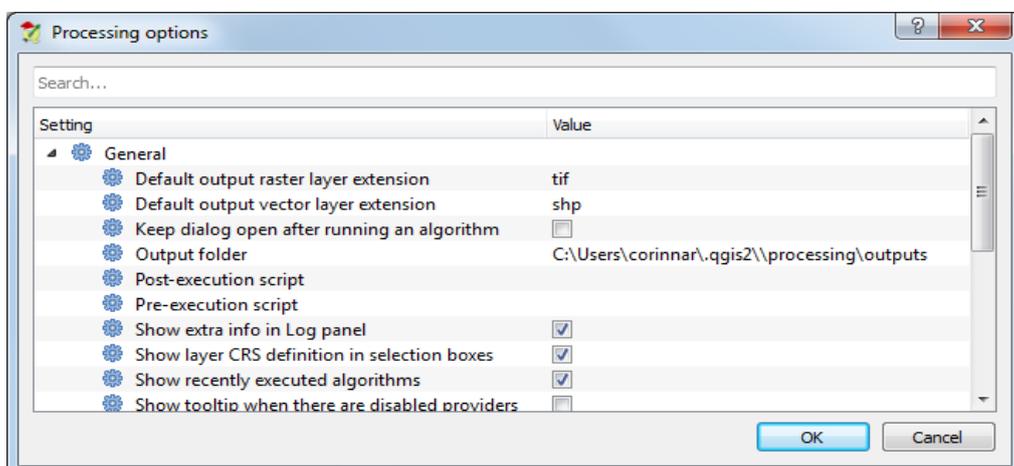
- **Output extent (xmin, xmax, ymin, ymax)**
- **Cellsize**

In the graphical modeller there are also some model only tools which allow the user to set parameters **Raster layer bounds** and **vector layer bounds** which pick up a bounding box from a chosen raster or vector dataset to use as the extent.

As QGIS accesses algorithms from many different providers it is even more important to check that the steps in an analysis are producing a consistent result.

A.2.2. Workspaces

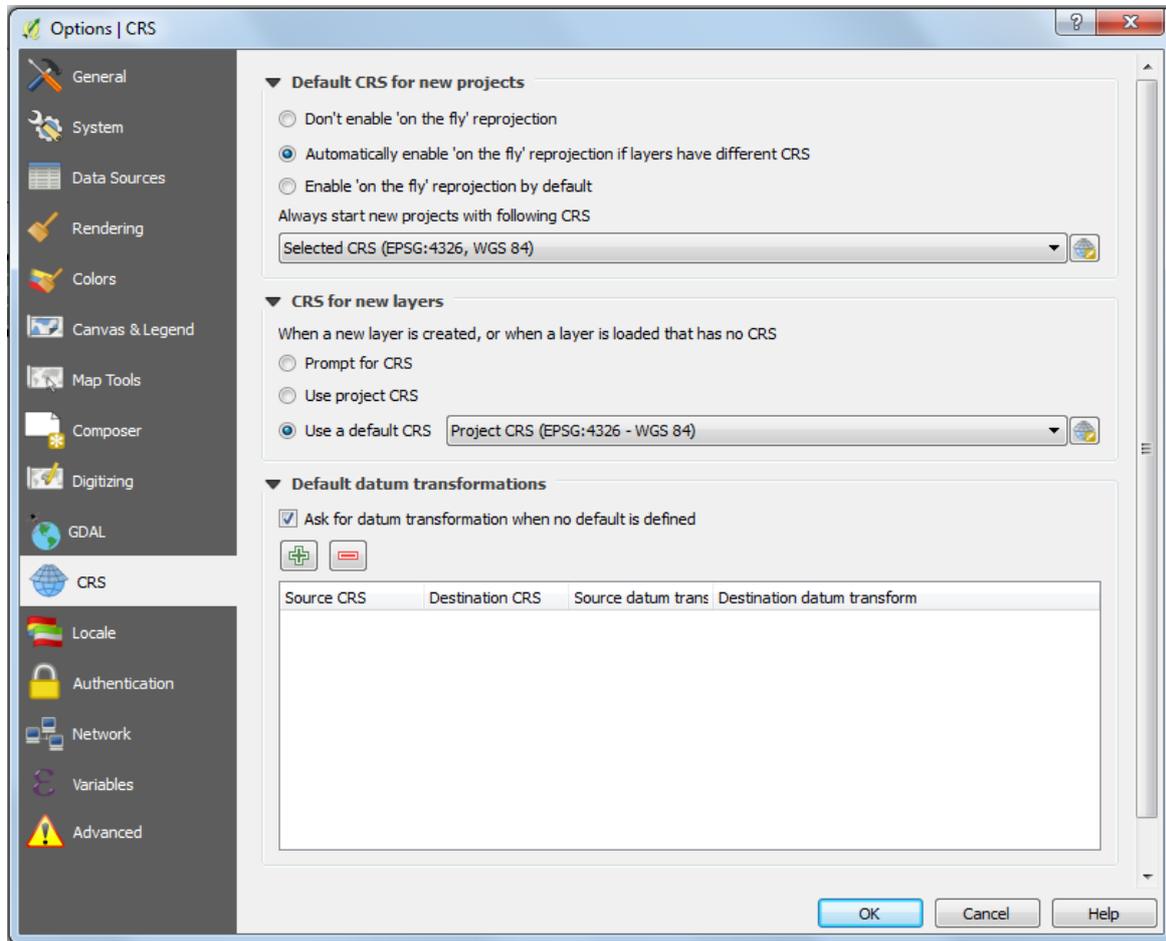
When performing any geoprocessing tasks in QGIS, you can choose whether the tool to produce a temporary or permanent output. For temporary outputs the resulting datasets are stored in the output folder specified in your procession options accessed from the **Processing** tab on the main menu bar.



A.2.3. Output Coordinates

In QGIS there are various options when setting the Output Coordinates system. You can pre-set the Output Coordinate System for the output datasets for the whole project.

- a. From the QGIS main menu click on **setting>>options**
- b. Click on the **CRS** tab



A.2.4. Cell size

Setting the cell size in raster analysis means that tools use this cell size for the output raster cell size, or resolution, for the operation. By default, the output resolution is determined by the coarsest of the input raster datasets **

*** It is important to read the help associated with the tool you are running to ensure that it is transforming the data to a different resolution in an appropriate way. In some cases it may be better to use the **resample** or **aggregate** prior to an analysis, as cells are resampled using nearest neighbour resampling in the environment settings and may not always be the most appropriate.*

A raster dataset can always be resampled to have a larger or smaller cell size, but this will not increase the level of detail of the dataset. Important factors for choosing cell size include:

- Spatial resolution of input datasets
- Type of analysis
- Size of output dataset
- Speed of running the analysis

Generally a **smaller cell size** should be used for **large scale data** with **high feature spatial accuracy** (so fine detail is retained), but viewing this over a large area can lead to slow drawing times. A **larger cell size** usually is selected for **small scale data**, as this means **faster drawing times**.

A.3. An Introduction to Some Raster Analysis Techniques in QGIS

The following guidance provide a brief introduction to some of the common raster analysis functions and finally how the **Raster Calculator tool** can be used to build more complicated expressions. The big difference between ArcGIS and QGIS when dealing with rasters is that in QGIS there is no raster attribute table associated with integer Rasters therefore some of the methods of calculating are different.

A.3.1. Standardizing Raster Data

There are two main methods: 1) Resampling and; 2) Aggregation

Method 1: resampling.

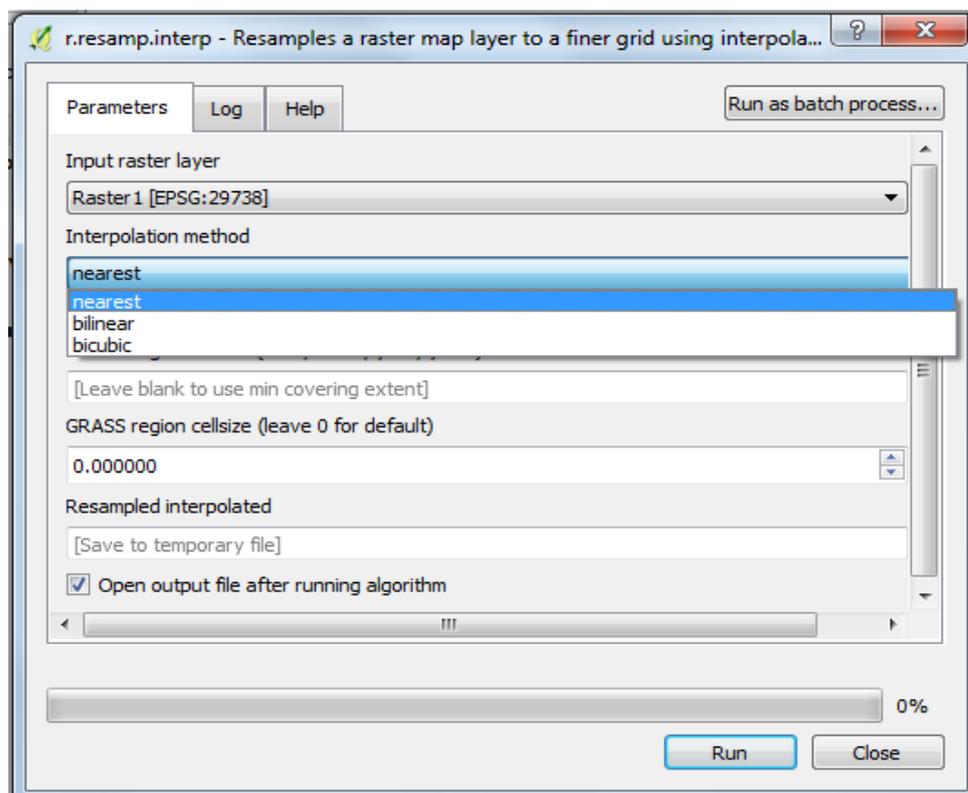
There are a choice of two tools that could be used which allows the user to change the cell size and choose the resampling method.

a. r.resample.inter (GRASS)

In this tool the default resampling method is **nearest**.

But users have the choice of 3 options:

- Nearest
- Bilinear
- Bicubic



b. Resampling (SAGA)

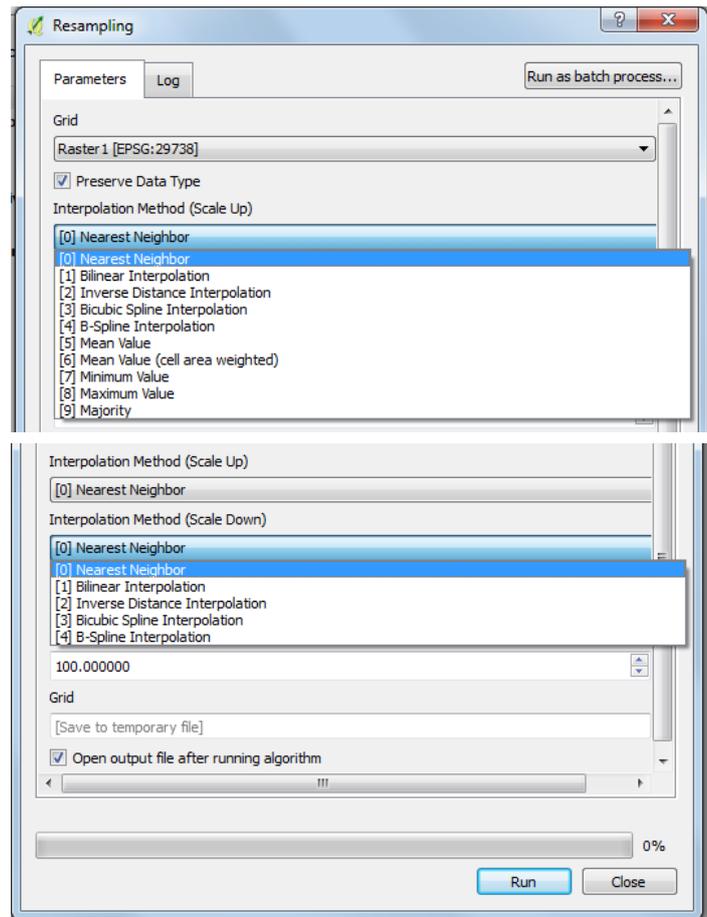
In this tool, the default is resampling method is **Nearest Neighbor**.

But users have the choice of 10 options for scaling up:

- Nearest Neighbour
- Bilinear Interpolation
- Inverse Distance Interpolation
- Bicubic Spline Interpolation
- B-Spline Interpolation
- Mean value
- Mean Value (cell area weighted)
- Minimum Value
- Maximum Value
- Majority

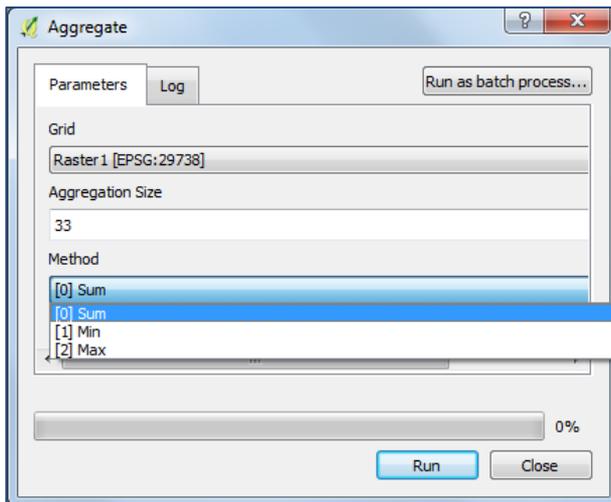
Or 5 options for scaling down:

- Nearest Neighbour
- Bilinear interpolation
- Inverse distance Interpolation
- Bicubic Spline Interpolation
- B-Spline Interpolation



Method 2: Aggregation

The **Aggregation tools** allows the user to choose a cell factor to create a reduced resolution version of a raster dataset. If a user wants to up-scale data from 30m cell size to ~1km cell size, an **Aggregation Size** of 33 would result in a cell size 33 times larger (i.e. 990m). The cell factor has to be a whole number greater than 1.



There are a choice of two tools that could be used:

c. Aggregate (SAGA)

In this tool, the default aggregation method is **sum**.

To determine how the output cell value is calculated the user has a choice of 3 options:

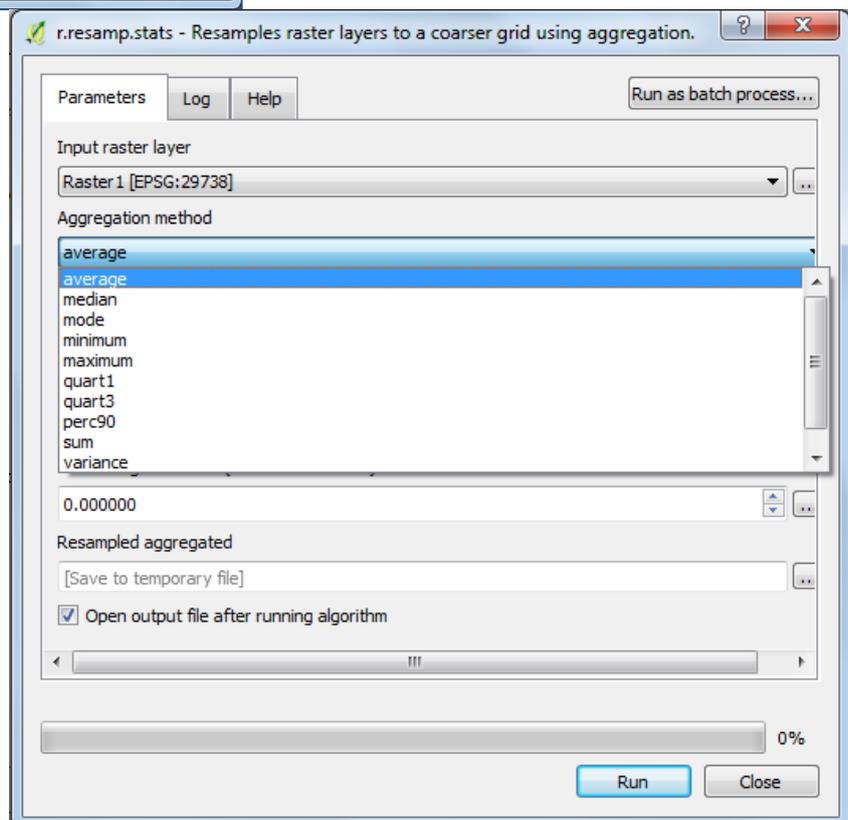
- Sum
- Min
- Max

d. r.resample.stats (GRASS)

The default aggregation method is **average**.

To determine how the output cell value is calculated the user has a choice of 10 options:

- Average
- Median
- Mode
- Minimum
- Maximum
- Quart1
- Quart3
- Perc90
- Sum
- Variance



The user specifies an output cellsize

Note that resampling and aggregating provide different methods for determining the output values of the cells. Resampling allows users to change to a smaller and larger cell size, but aggregation is for generalization to a larger cell size only.

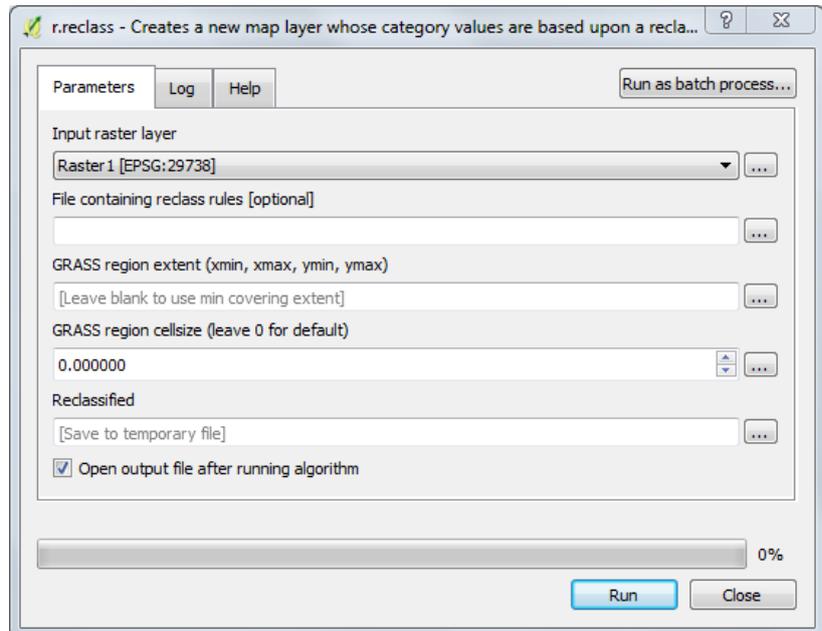
A.3.2. Reclass functions

Many raster processes use the value field when processing data. You may want to group data or change the values in a raster dataset.

There are a number of reclassify tools that can be used.

a. **r.reclass (GRASS)**

Reclass rules are contained in a txt file (see the tool help for details on how to create the reclass file).



b. Reclassify values (SAGA)

This tool provides various options for reclassifying a from a single value, a range of values or using a look-up table.

It also provides an option for converting No Data values to another value.

Reclassify values

Parameters Log Run as batch process...

Grid
Raster1 [EPSG:29738]

Method
[0] single

old value (for single value change)
0.000000

new value (for single value change)
1.000000

operator (for single value change)
[0] =

minimum value (for range)
0.000000

maximum value (for range)
1.000000

new value(for range)
6.000000

operator (for range)
[0] <=

maximum value (for range)
1.000000

new value(for range)
6.000000

operator (for range)
[0] <=

Lookup Table
Fixed table 3x3

operator (for table)
[0] min <= value < max

replace no data values
new value for no data values
0.000000

replace other values
new value for other values
0.000000

Reclassified Grid
[Save to temporary file]

Open output file after running algorithm

0%

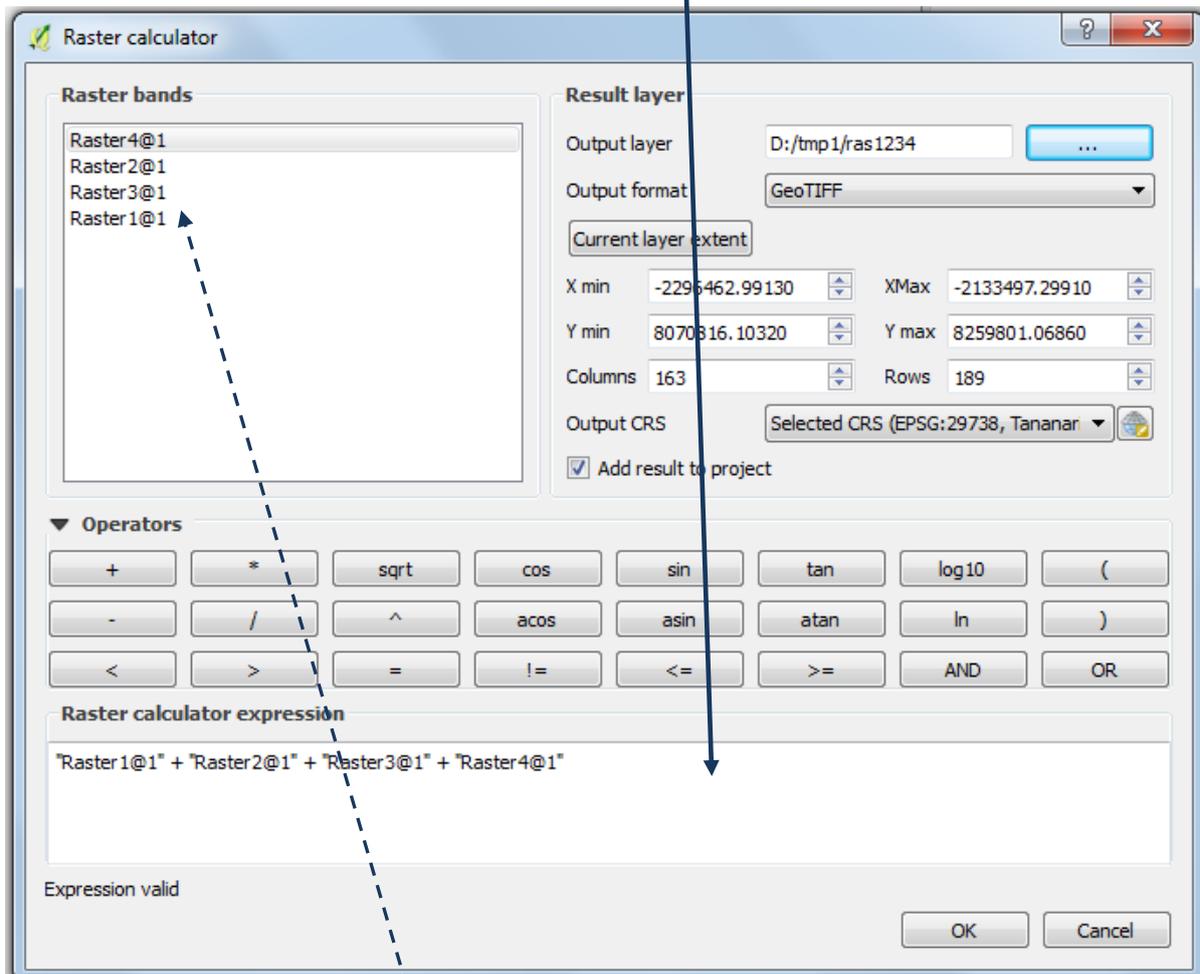
Run Close

SAGA also provides a simpler version of this tool with options is available in the **Reclassify values (Simple) tool**.

A.3.3. Raster calculator: Overview

You can also run raster tools using **Map Algebra** expressions typed into a **Raster Calculator tool**. Map Algebra expressions can be used to run a single tool or operators, or to create a more complex string of tools or expressions. In QGIS there are 3 different Raster calculators. The main QGIS Raster calculator can be accessed from the main menu (but it is important to note that this one cannot be accessed through the processing toolbox or the graphical modeler). The other two are the **GRASS r.mapcalculator** and the **SAGA Raster Calculator**. We will illustrate the core QGIS Raster Calculator tool here. Syntax for the different raster calculators varies and further guidance can be found in the QGIS, GRASS and SAGA help documentation.

In the QGIS Raster Calculator, the expression is typed in the bottom panel. In this example four raster datasets are being summed together.



2	5	0	1	0	1	2	1	1	2	1	5	=	7	7	7
8	6	1	0	1	0	1	1	1	0	0	3		9	8	5
5	1	1	0	1	1	1	3	1	3	3	3		9	8	6
Raster1		Raster2		Raster3		Raster4		Output Raster							

- c. The **left hand panel** shows the **list of layers** that can be used in the expression. These are the raster layers that you have added to your ArcMap session. By double-clicking on a layer it will bring it into the expression box in quotation marks (and places an @1 after the name).

- d. The middle panel contains a list of operators. Click once on these to add to the expression box. There are simple operators to **Add (+)**, **Subtract (-)**, **Divide (/)** or **multiply (*)**

The middle panel also contains operator's equivalent to the **Boolean logic**:

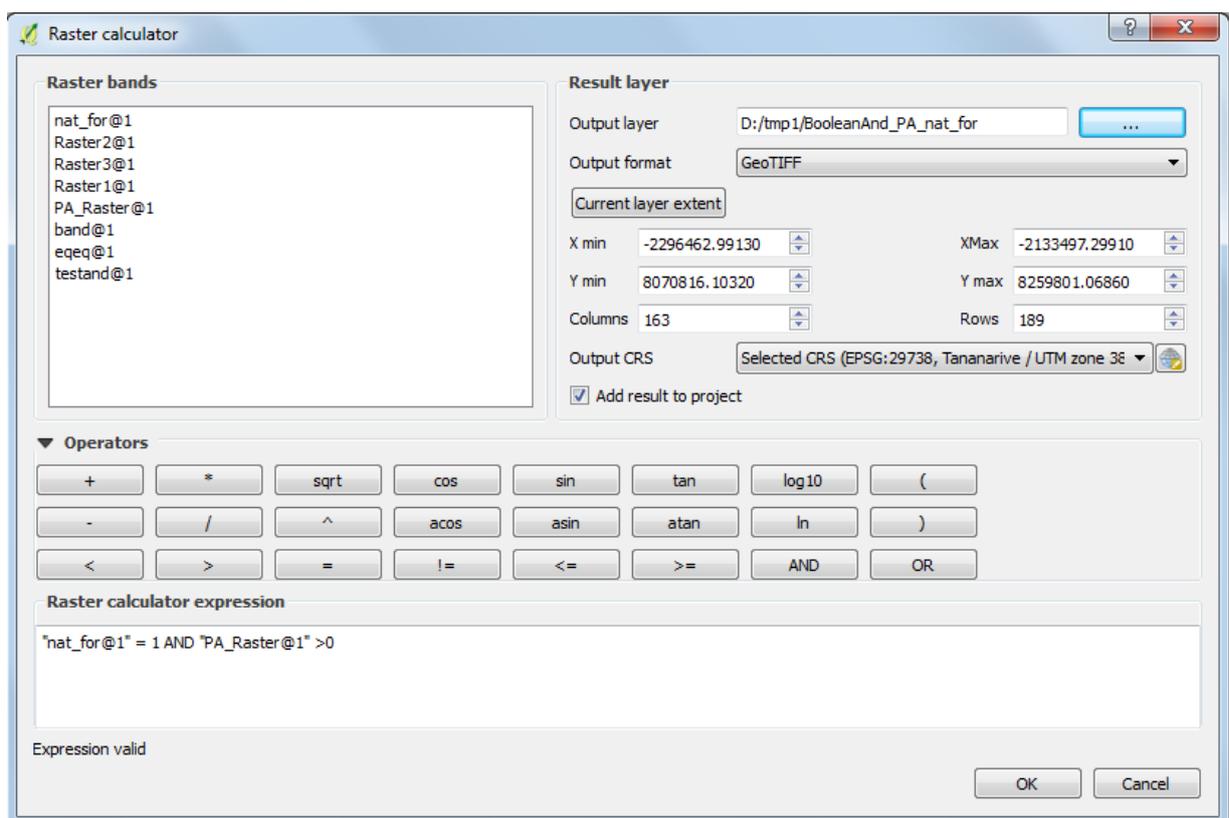
AND Boolean And	!= Not Equal to	>= Greater than or equal to
OR Boolean Or	> Greater than	<= Less than or equal to
= Equal to	< Less than	

A.3.4. Raster Calculator: Boolean Intersection and no data conversion

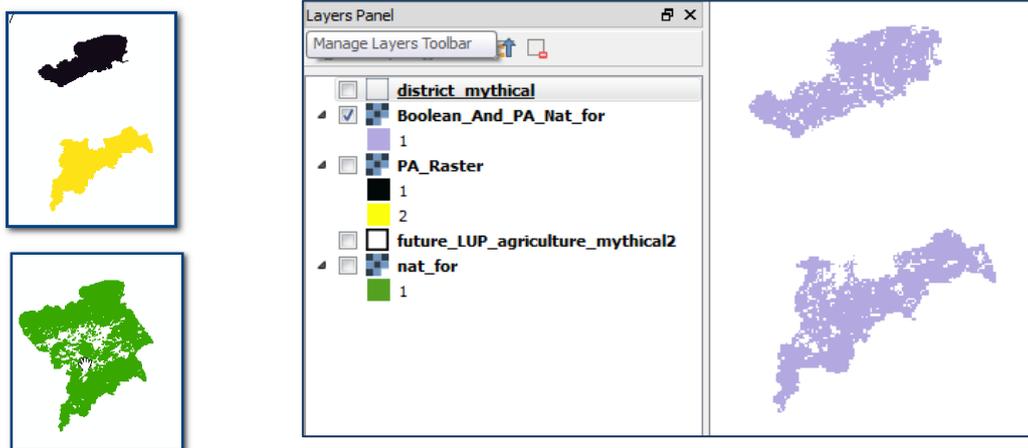
Boolean intersection is the simplest variant of criteria processing and is often referred to as constraint mapping. Prior to the combination, each input criteria is standardized to a certain scale of suitability (or reclassified into classes of 1 and 0), i.e. reducing all the factors to Boolean raster datasets of suitable and unsuitable areas.

In an example **Boolean And** analysis, where data for forests contain the value of 1, and data for Protected Areas contain the values of 1 and 2, and outside of Protected Areas and outside of forest area has **No Data** value, the output raster is 1 where forests and Protected Areas coincide. Remaining areas are classified as **No Data**. The syntax in the Raster Calculator is:

```
"nat_for@1" = 1 AND "PA_Raster@1" > 0
```



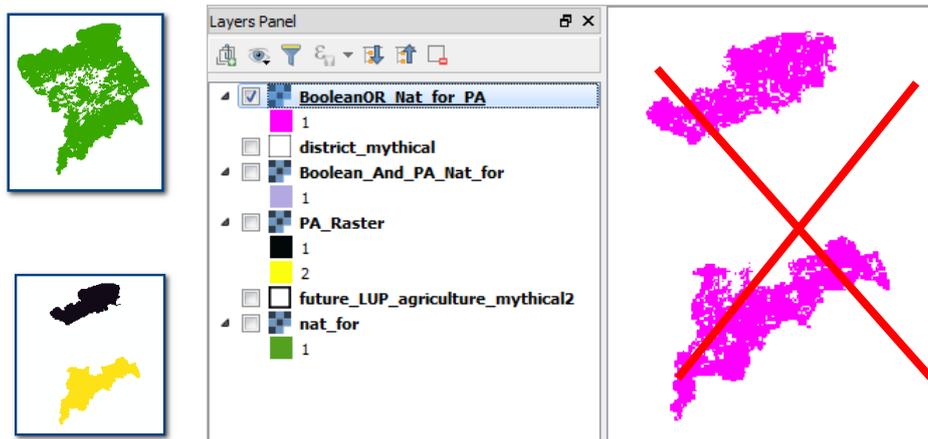
The input datasets are illustrated on the left and result of the calculation on the right:



The No Data is not a problem with the **Boolean And tool** analysis, as the analysis is selecting values present in BOTH datasets only. When it comes to MOST OTHER tools in the logical toolbox you will see that No Data values can cause problems and it is necessary to convert them to 0 before using the data (see section 1.4.1 on how to convert No Data values into data).

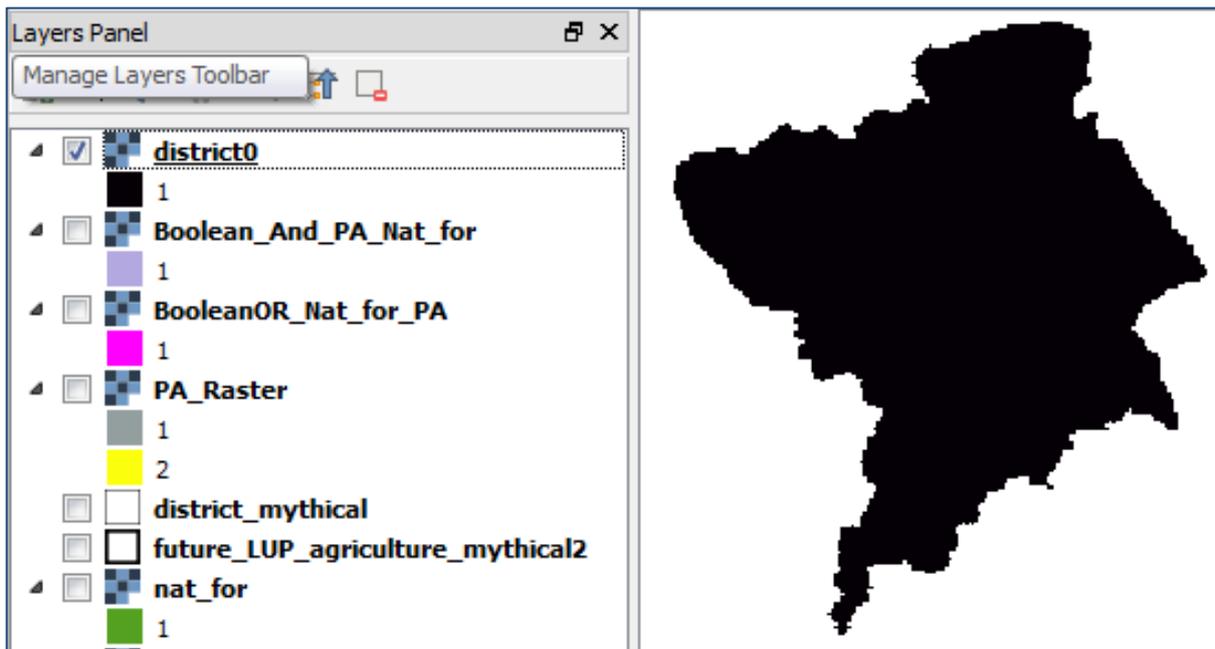
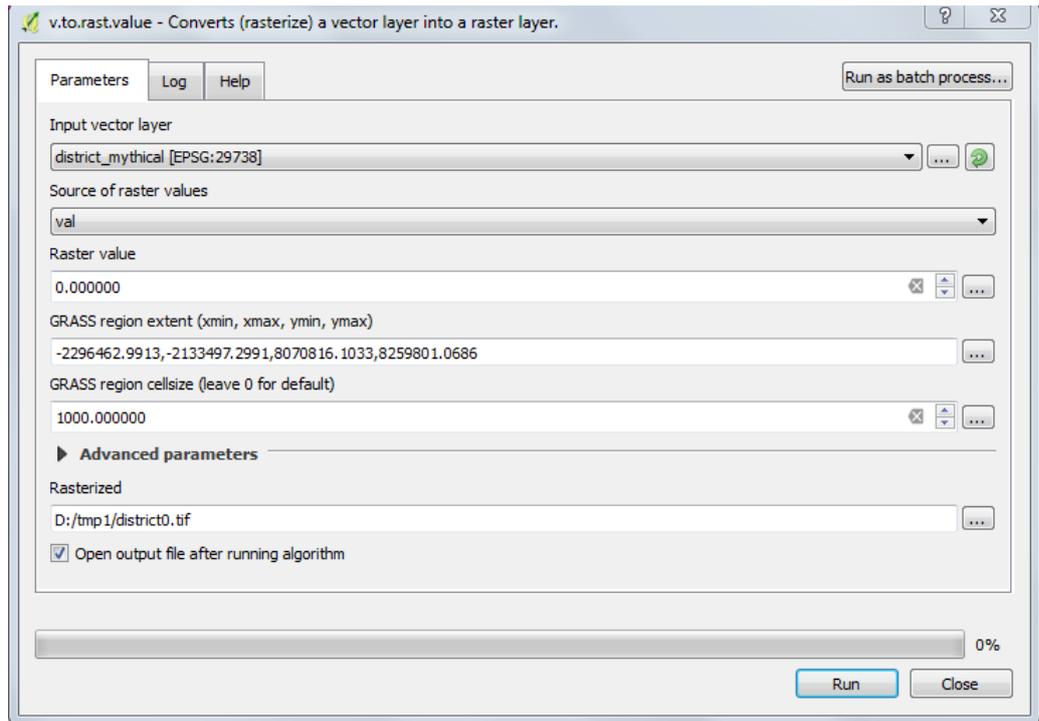
The **Boolean Or** function selects where data values are greater than 0 in either of the two datasets. However, if No Data values are present in either of the datasets, this will take precedence over any other value and acts as an additional constraint. For example, if a cell has a value of 1 in the forest dataset and a value of No Data in the Protected Area dataset, the output cell would receive a value of No Data. ***** So, with No Data values present in the input layers, the output from the Boolean OR will be WRONG!*****

The syntax in the Raster Calculator is: "nat_for@1" = 1 OR "PA_Raster@1" > 0

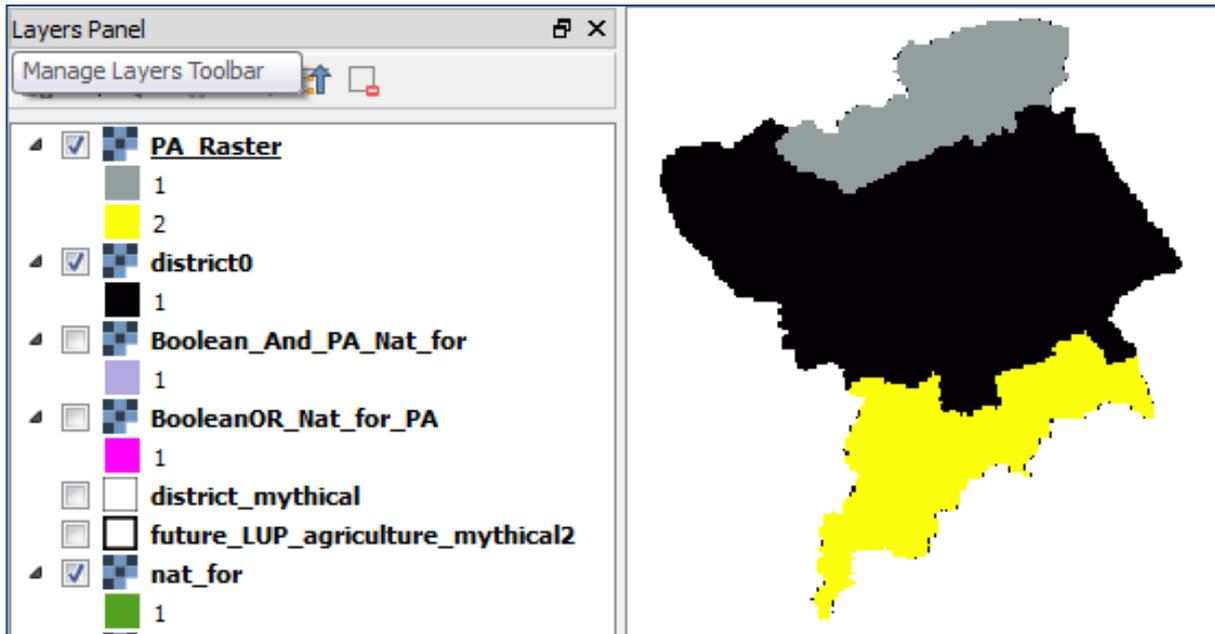


The result should display values of 1 where protected area OR natural forest is present. No Data values therefore need to be changed to 0.

To convert the no data values in the protected areas raster to 0 we can use the district vector to create a new layer for the district all values are set to 0 using the GRASS **v.to.rast.value** tool.

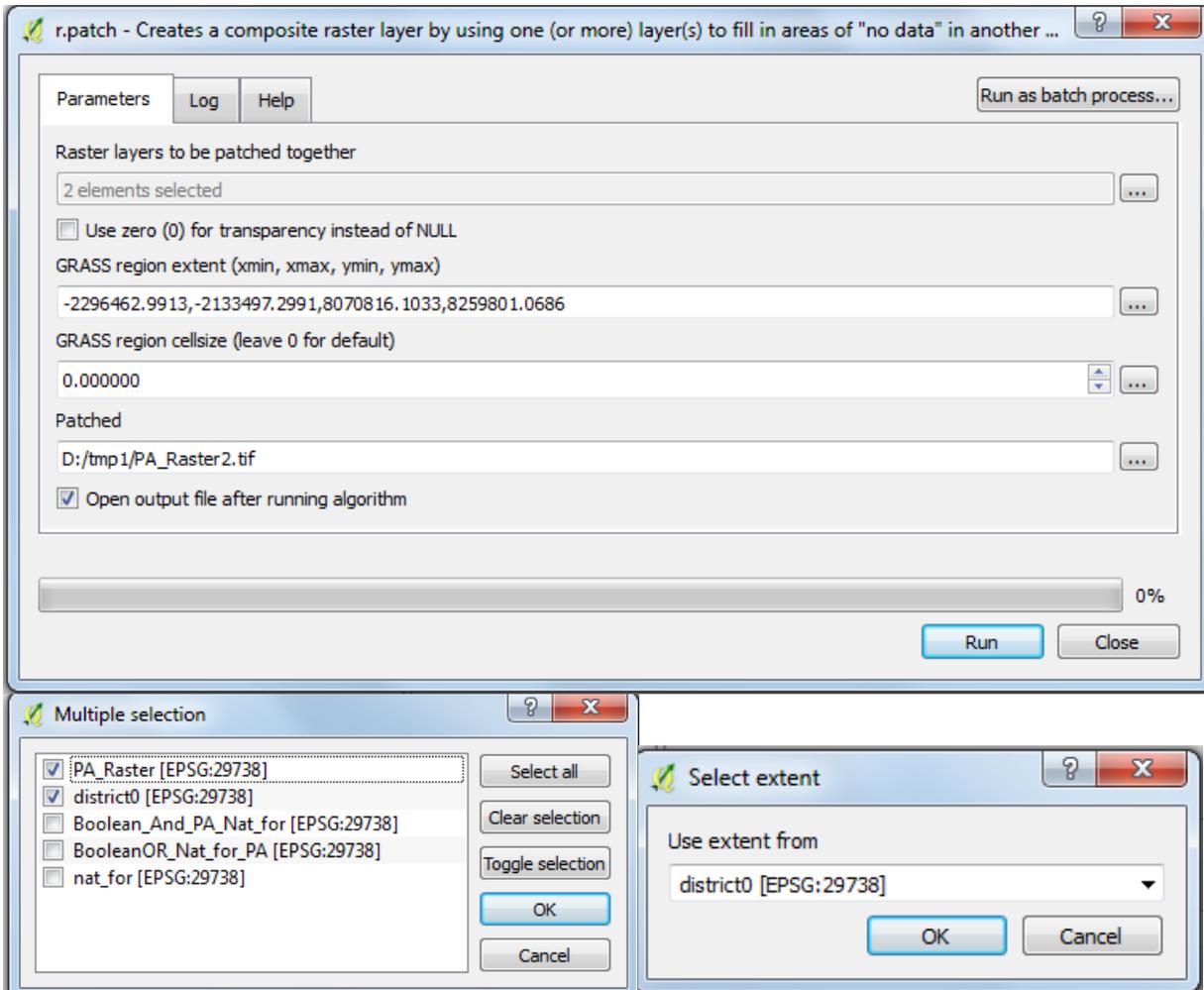


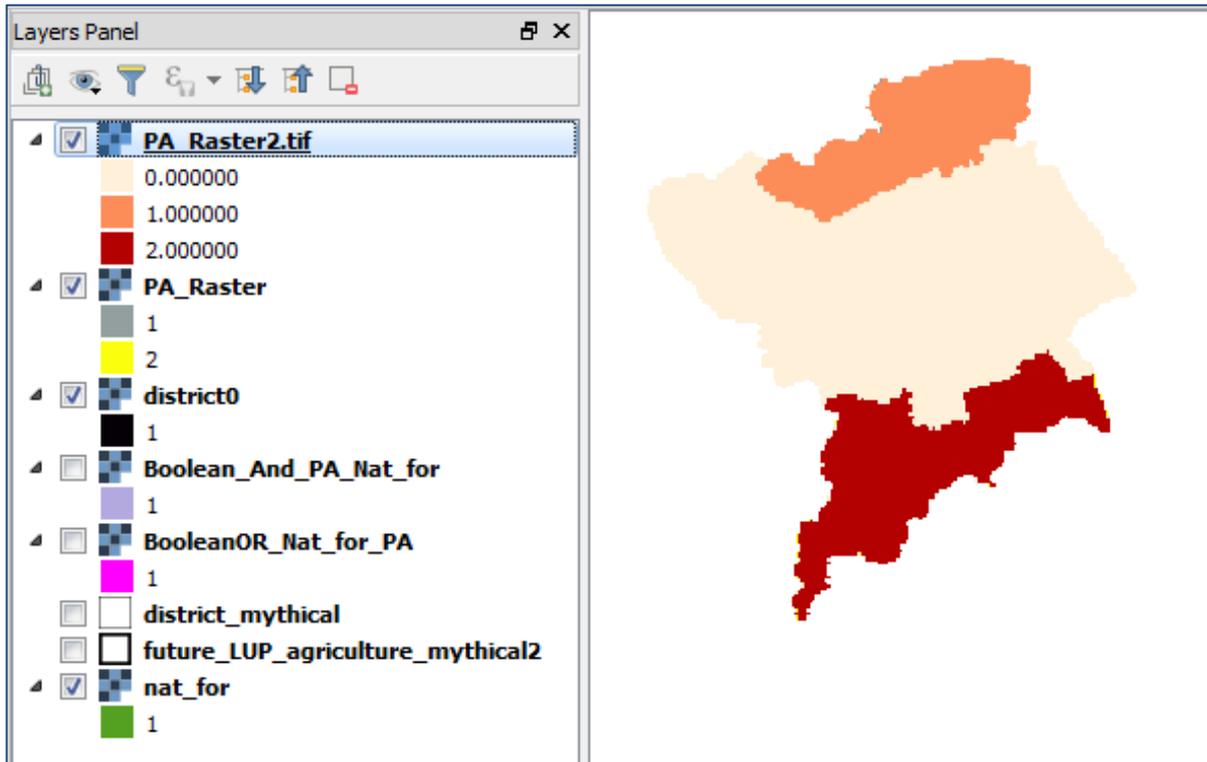
The next step is to merge the districts with the Protected Areas so the area within the district that is not protected has a 0 instead of no data. In order to do this the Protected areas layer needs to be moved above the district raster in the table of contents.



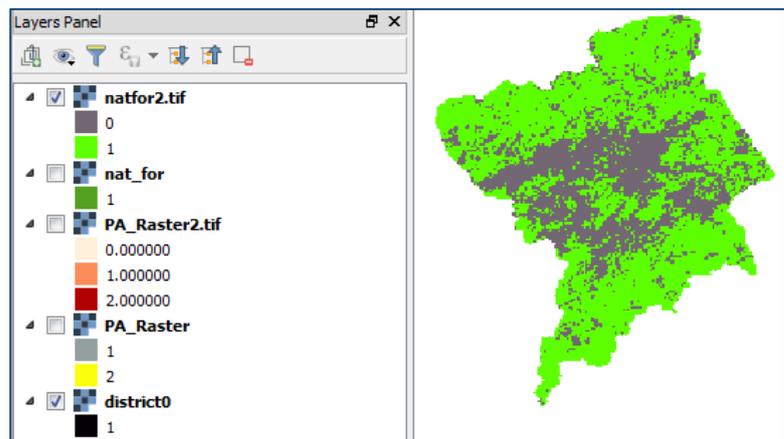
Then the GRASS `r.patch` tool is used to merge this layer with the protected areas layer. The tool will take the values in the top raster as precedence over values in the bottom raster.

The raster layers to be patched together should be ticked and the extent is set to the full extent of the area of interest, i.e. in this example to the full extent of the district



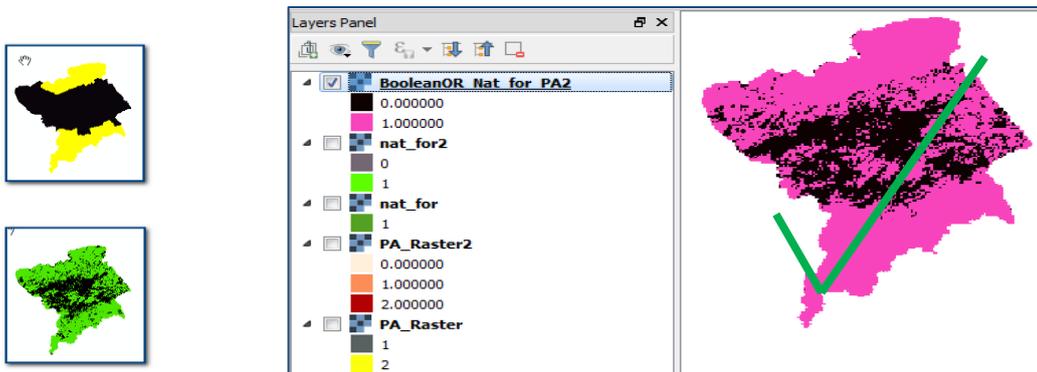
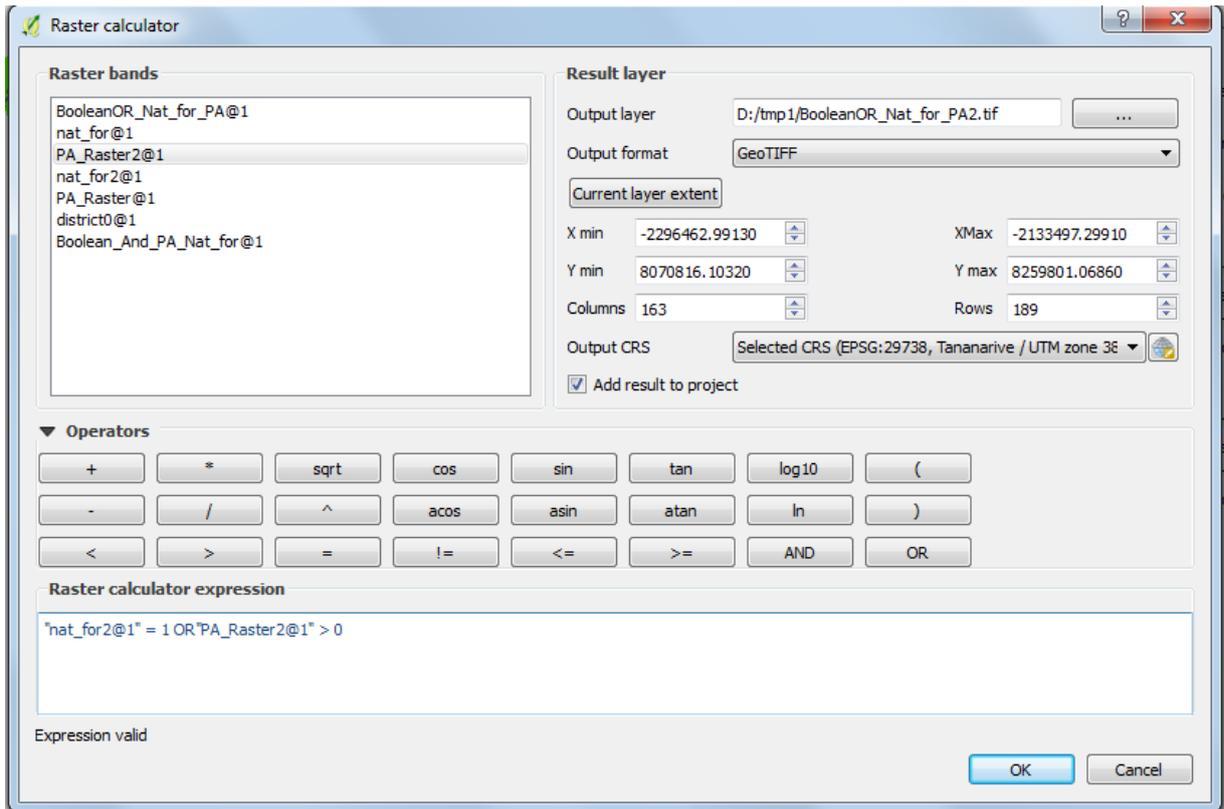


The forest layer also needs to be moved above the district raster in the table of contents and merged with the district raster using the `r.patch` tool.



Once both layers cover the full extent and have had their no data converted to 0 the Boolean OR expression can be entered into the Raster Calculator. The syntax in the Raster Calculator is:

`"nat_for2@1" = 1 OR "PA_Raster2@1" > 0`



A.3.5. Zonal statistics

Zonal statistics tools are very useful. They can be used to summarize an input raster data layer by a zone layer. The **Zone** layer can be either vector or raster and can, for example, be used to summarize the amount of different forest types within individual protected areas.

This guidance has presented only a few tools in detail, to help to get users started on raster analysis and should not be seen as a comprehensive guide. Users can explore the toolboxes in QGIS for themselves to find and identify tools that may be relevant to the question they are trying to answer.

Annex 2: Additional QGIS Graphical Modeler Resources

- Tutorials
- Online Examples:
 - http://docs.qgis.org/2.0/ca/docs/user_manual/processing/modeler.html
 - http://www.qgistutorials.com/en/docs/processing_graphical_modeler.html
 - <http://gis.stackexchange.com/questions/176599/simplify-repetitive-tasks-in-qgis-graphical-modeler>
 - <http://www.digital-geography.com/creating-models-qgis/#.WEgN7rKLSM8>
 - [http://gracilis.carleton.ca/CUOSGwiki/index.php/Automating Vector and Raster Workflows using the Graphical Modeler in QGIS](http://gracilis.carleton.ca/CUOSGwiki/index.php/Automating_Vector_and_Raster_Workflows_using_the_Graphical_Modeler_in_QGIS)